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GENERAL ELECTRIC Review

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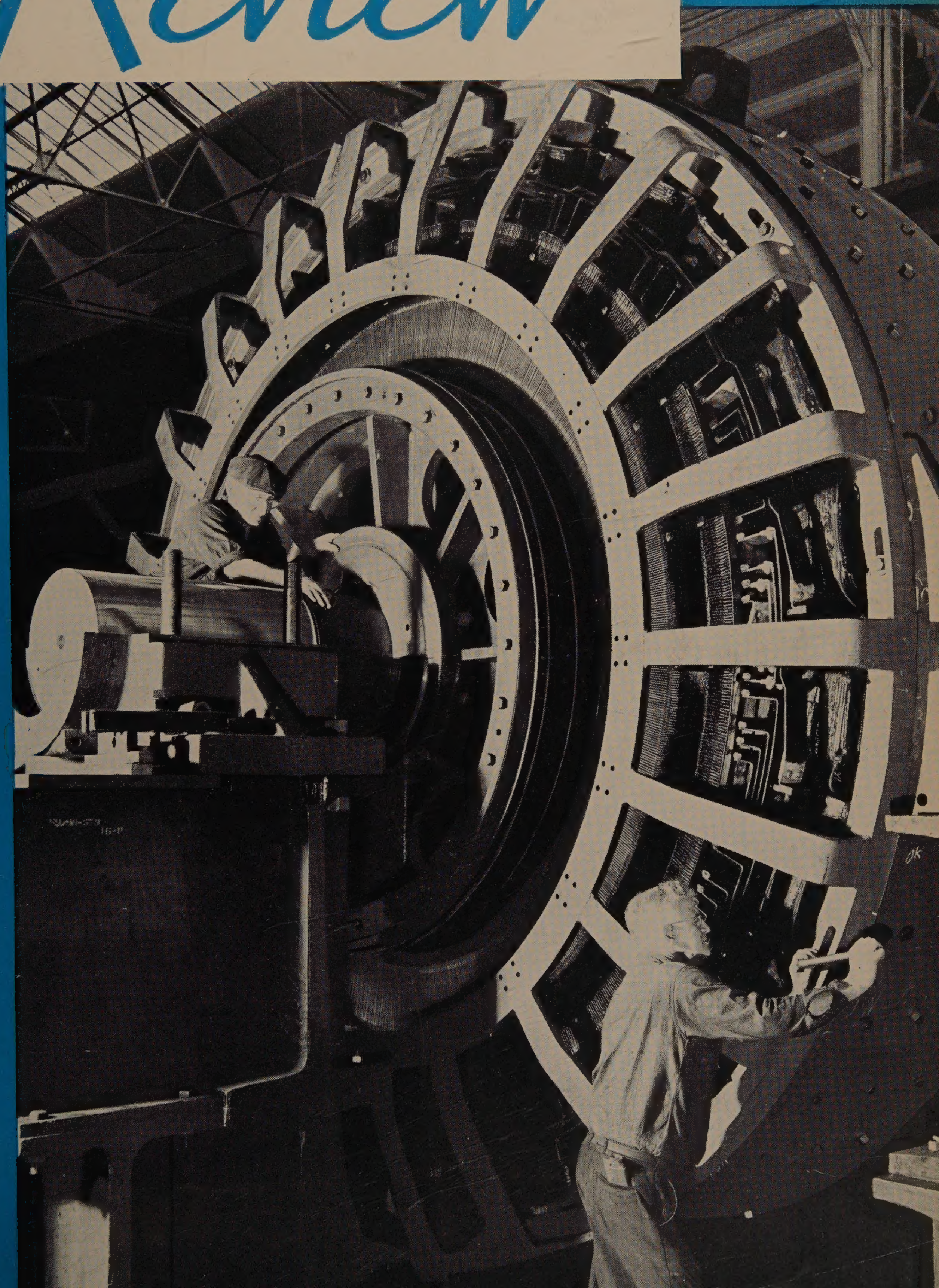

JULY
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New Property Chart of ALSIMAG®
TECHNICAL CERAMIC COMPOSITIONS

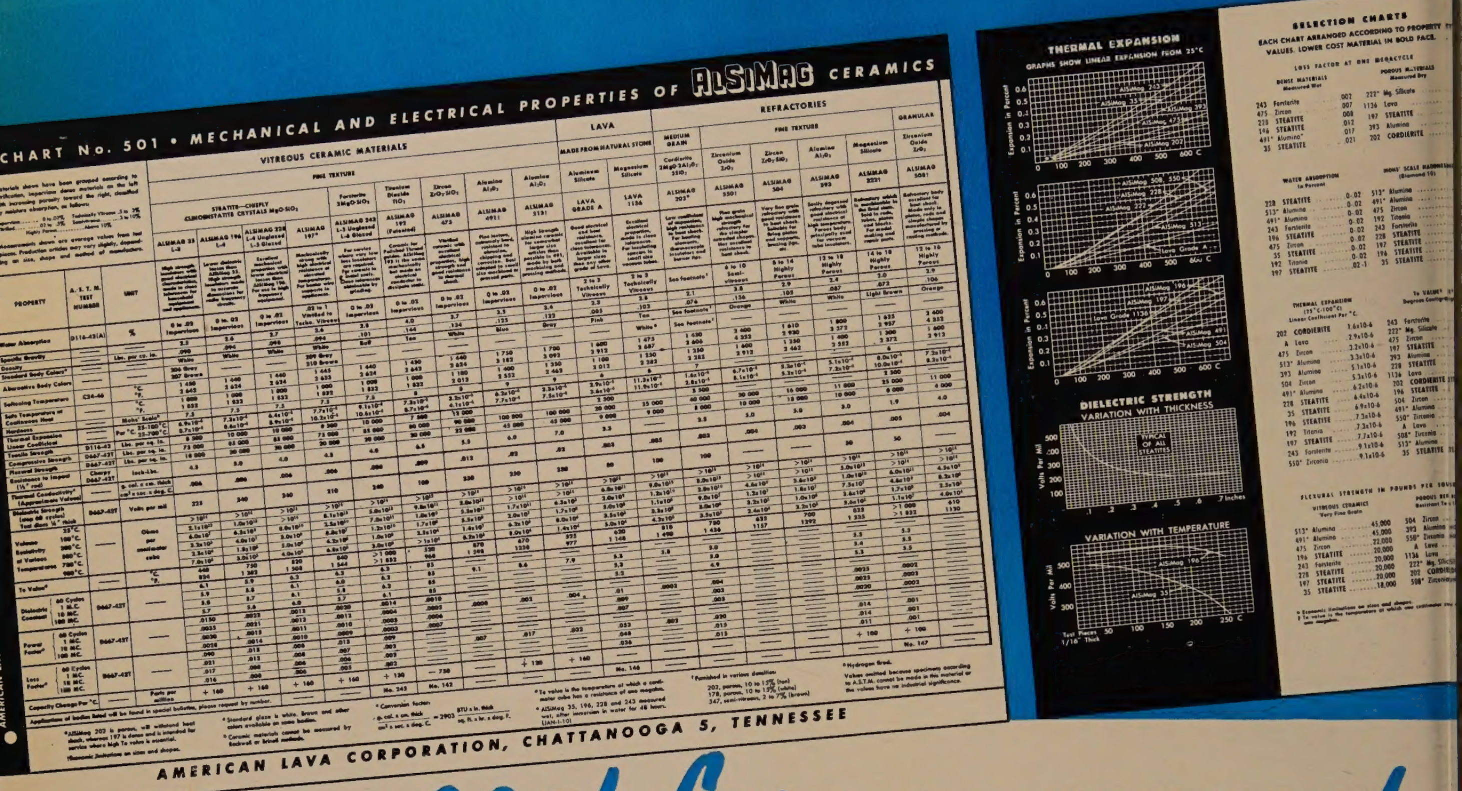


CHART No. 501 • MECHANICAL AND ELECTRICAL PROPERTIES OF ALSIMAG CERAMICS

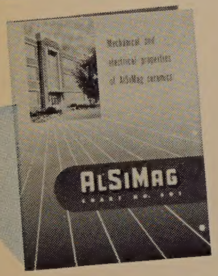
THERMAL EXPANSION

DIELECTRIC STRENGTH

SELECTION CHARTS

AMERICAN LAVA CORPORATION, CHATTANOOGA 5, TENNESSEE

sent free on request



American Lava Corporation, Chattanooga 5, Tennessee, has issued a new chart giving the mechanical and electrical properties of AlSiMag custom-made technical ceramics.

WHAT ALSIMAG IS

AlSiMag is the trade name of a large family of technical ceramic compositions. These compositions have different physical, electrical, mechanical and chemical characteristics. AlSiMag ceramics are custom-made to specifications.

WHAT THE CHART TELLS

The chart covers seventeen of the more frequently used AlSiMag compositions and is the most complete chart yet issued in this field. A new feature is a selection chart which simplifies and speeds the selection of the most useful composition for the individual requirement. This selection chart indicates lower cost materials in BOLD FACE. This helps the product engineer to design for utmost economy.

Some properties, such as thermal expansion, dielectric strength, in relation to thickness and temperature are presented in graphic form.

ALSIMAG COMPOSITIONS NOT ON CHART

Many special AlSiMag compositions have been developed to meet specific conditions. These are too numerous to chart. If chart indicates general characteristics of value, modifications to suit your special application may be available.

WHO NEEDS THE CHART

Designing engineers, production technicians or purchasing agents will find chart helpful in their search for materials for unusual applications.

HOW TO GET THE CHART

The AlSiMag Property Chart is sent free on request. Request as many copies as you need to cover your organization.

WHERE ALSIMAG IS USED

AlSiMag custom-made technical ceramic parts are extensively used as: Insulators for the electronic field • Insulators for electric appliances and other electrical applications • Thread Guides for textiles, wires, paper twine, etc. • Extrusion dies for such products as pencil leads, battery carbons, soft wires, explosives, etc. • Gas burner tips • Controlled atmosphere welding tips • Oil burner ignition insulators • Ceramics for hermetic seals • Metal-ceramic combinations • Air-acid jet nozzle inserts • Polishing heads for delicate final polishing operations • Cores and inserts for precision castings • Strainer cores for metal foundries • Cut-off cores for metal foundries • Refractory pins and plates in small sizes and special shapes • Work holders for electronic heating devices • As a replacement for parts made of plastic, wood or machined metal wherever a wear resistant part is required • In short, wherever electricity, heat, chemical or certain abrasive or friction conditions must be controlled.

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GENERAL ELECTRIC Review

JULY 1950
Vol. 53, No. 7

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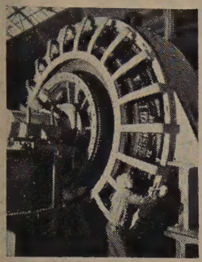

THE COVER

The simple statement "believed to be the largest nine-hoist motor in physical size ever built in this ountry" applied to this 3000-hp d-c machine (shown iere being assembled on the factory floor in Schenectady) adequately describes this piece of equipment or certain purposes—perhaps even, as the saying oes, "for all practical purposes" if we add the statement "capable of lifting 12 tons of ore nearly half a nile a minute." Terminology employed in ratings nust be more explicit, particularly for voltages of -c equipment. This is the subject of the article eginning on page 36.

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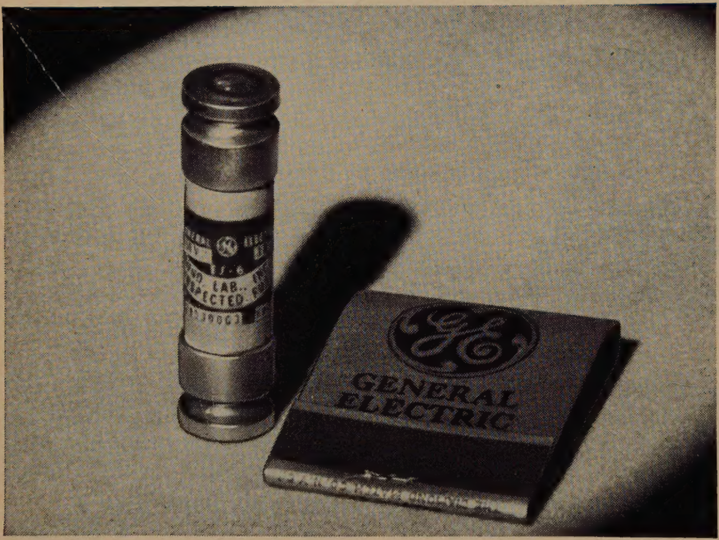

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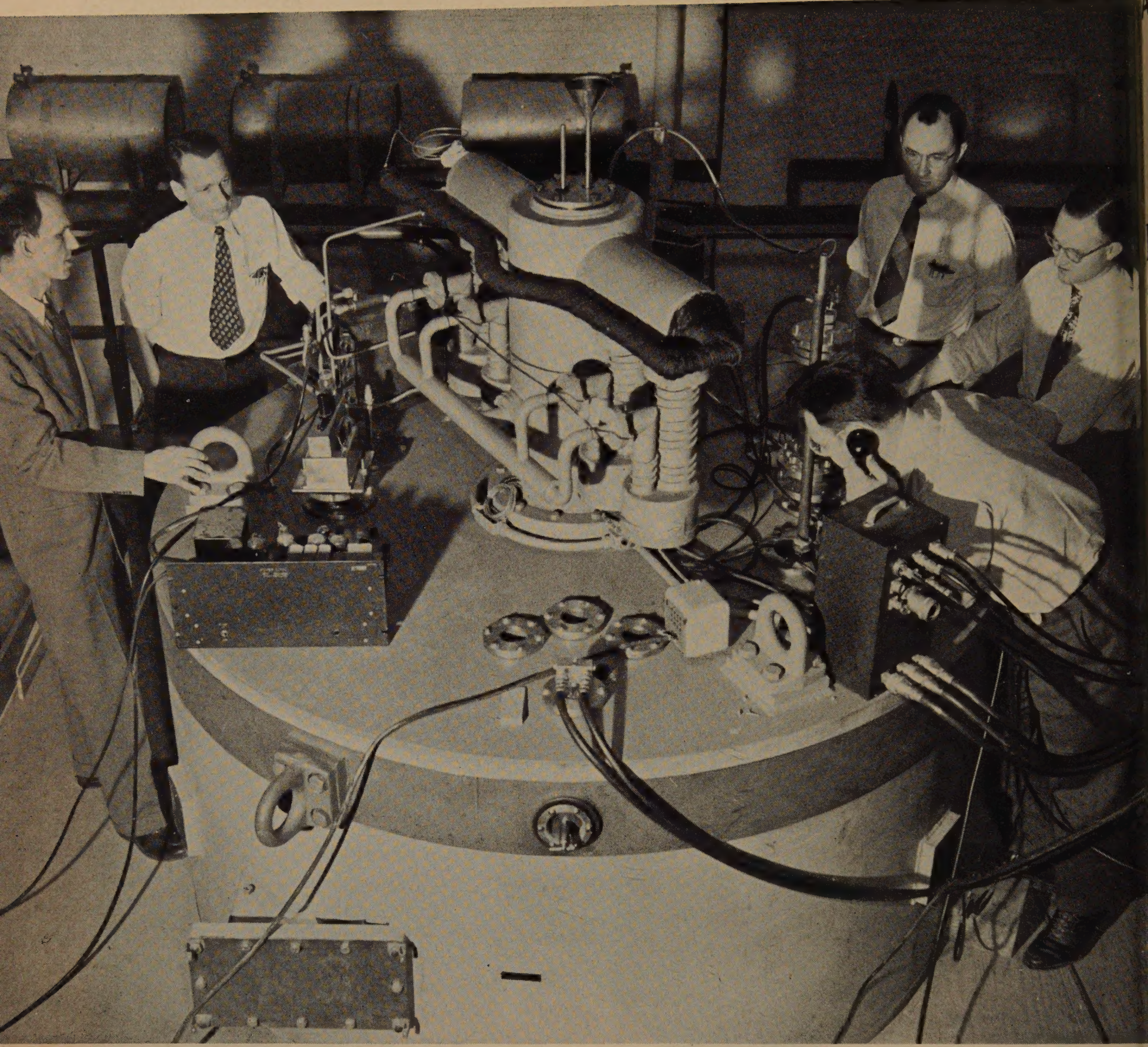

ADJUSTING A NEW TYPE OF SYNCHROTRON

A nonferromagnetic synchrotron with wire coils instead of an iron-core electromagnet—designed for producing 300,000,000-volt x-rays—has been built under the joint sponsorship of the Office of Naval Research and the General Electric Research Laboratory. The machine has been operated in its first phase and will be used in studying effects of high-energy radiation. (*See p. 45*)

ATOMIC ENERGY'S PLACE IN YOUR PLANS FOR THE FUTURE

By HARRY A. WINNE
Vice President, In Charge of Engineering Policy
General Electric Company

HERE are a few fundamental facts that may help in gaining a little better picture of how atomic enrgy may possibly, or even probably, enter into the iture of the electric-power industry.

Unfortunately, there seems to be no possibility of irect conversion from the splitting atom to electric ower. The usable energy released in an atomic pile is in he form of heat. Just as the heat generated in the comustion space in an oil-fired boiler is carried away by the team, so the heat released in an atomic pile must be arried away by a heat-transfer medium, such as a gas r a liquid.

It is not practical to generate steam within the ile itself, for two main reasons. First, the steam eaving the pile would be radioactive, and consequently he turbine, condenser, and all piping would need heavy hielding. Second, fluctuations in the water level would isturb the nuclear equilibrium within the pile, introucing a very difficult control problem.

The power pile which General Electric is designing vill use a low-melting-point liquid metal as the primary ieat-transfer medium. This liquid metal will be pumped hrough the pile, absorbing the heat generated and arrying it to a heat exchanger. All this part of the equipnent will be very radioactive and must be heavily hielded. In the heat exchanger, water will pick up the ieat, producing steam to supply a turbine. The steam iping and turbine will need no shielding.

For a better understanding of the situation, it is iecessary to consider also some facts about the atomic ile itself. When an atom of U-235 is hit by, and abiorbs, a sub-atomic particle called a neutron, it splits nto two parts, releasing a lot of energy, and—this is nost important—spills out two or three other neutrons, vhich then are ready to contact other atoms of U-235 ind thus keep the chain reaction going. Now, less than ne percent of natural uranium bears the magic U-235 abel, so if we use natural uranium as a fuel the active art of the pile must be physically large.

If we use concentrated U-235, extracted from natural iranium, or one of the artificial elements, such as lutonium, or U-233, which can be produced in an tomic pile, then the active part of the pile can be made nuch smaller, and the factor which determines the hysical size is the necessity for providing enough heatransfer surface.

But regardless of how small we make the active part of the pile or reactor, it must be surrounded on all sides by a shield to protect personnel from deadly radioactivity. This shield must be thick and heavy—the equivalent of, say, five to ten feet of concrete. Incidentally, the intense and long-persistent radioactivity of the pile structure after it has been in operation introduces a lot of problems in maintenance. However, in our operations at Hanford we have found that these problems are not insuperable.

The heat output rate of a pile can be controlled quite easily and simply. As stated earlier, an atmosphere of neutrons is necessary to keep the chain reaction going, just as an atmosphere of oxygen is required to keep a coal or oil fire burning. Now it so happens that there are certain elements, of which boron is one, which have a great affinity for neutrons, but which simply absorb them and don't release any others. So, in the piles at Hanford there are a lot of boron-coated steel rods which can be moved into or out of the pile by remote control. To lower the power output, the operator simply pushes a button which causes a rod to move farther into the pile, so it eats up more neutrons, leaving fewer available for the chain reaction, and the power output drops. It really is simpler than controlling an oil-fired boiler.

Yes, control is easy, but there are still a lot of technical problems to be solved in building a power-producing pile to operate at the high temperature necessary for good efficiency.

These problems are being attacked in a number of places, including the Knolls Atomic Power Laboratory which General Electric is operating for the Government at Schenectady. This is a $25,000,000 facility, staffed by about 1400 people, of whom 250 are technical.

The power pile which General Electric expects to construct near Schenectady, for the A.E.C., was originally intended to be a small developmental land power plant. Now, however, in order to implement the present thinking of the Atomic Energy Commission as to the importance of military developments, this is being designed as a prototype of a naval-ship power plant. As had been expected, the Company's experience in operating Hanford is proving very helpful in the developmental work on the power pile.

I am certain that our technical problems will be solved. If that statement is taken at full face value, then probably at least four major questions arise in mind. First, is there enough atomic fuel; second, how many

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This article is so paged that, without mutilating other articles, it can be eadily removed for filing as a group of full-size consecutive pages.—EDITOR dollars; third, when; fourth, how much government control? Let's consider these briefly.

I believe we shall have an adequate atomic-fuel supply in the long-term future. Uranium is a fairly abundant element. Although presently known concentrated deposits are few, methods are being developed for working the low-grade ores. True, the fissionable U-235 constitutes only 1/140 of natural uranium, but here is where breeding and conversion come in.

As mentioned earlier, when a U-235 atom grabs a neutron and splits, it releases from two to three more neutrons. Now only one of these is needed to split another U-235 atom and thus keep the chain reaction going. The remaining one or two can go wandering around in the pile looking for other playmates. If one lands on an atom of U-238, the much more abundant kind of natural uranium, an atom of plutonium is produced, and plutonium is a fine atomic fuel. So we have used up one atom of fuel, released its energy, but have in addition a new atom of fuel.

In the piles at Hanford we are doing just about this, but we believe it is possible to build a pile which will be a real breeder and, on the average, use more than one of the extra neutrons for new fuel production. If we can do this we shall generate power and end up with more atomic fuel in the pile than we had at the start. Furthermore, the much more abundant element thorium can be converted to fissionable material in the same way. So I think we can have plenty of fuel. Consider also that the energy from one pound of fissionable material is equal to that from burning about 2½ million pounds of coal.

Now we come to cost, and this item we know but little about. A recent A.E.C. paper states that the average cost of presently planned experimental reactors is something over $10,000 per equivalent electrical kilowatt output. Not exactly cheap! But that should not discourage us. Fifty years ago the theory of the gas turbine was known just as the theory of the reactor is today. But suppose the building of a power-producing gas turbine at that time had been a command performance, like the development of the atomic bomb. I imagine the buckets and combustion chambers might have been made of platinum! What do you think the cost per kilowatt of such a unit would have been? And that's about where we are today in the atomic-power field.

And now, when? In my opinion, a long time—twenty to forty years perhaps before atomic energy can have any effect on our electric-power industry. Developmental power-producing piles probably will be operating within three to five years—we hope to have a ship-propulsion prototype going by that time—but the bigger piles will come more slowly, and the real time-determining factor will be economic. Tremendous governmental expenditures can accelerate remarkably the development of a gadget such as an atomic bomb, or a developmental power plant, but I think we cannot greatly collapse the time cycle for the economic development of such a fundamental phase of an industry. Let's think of the gas turbine again. Would millions of dollars expended in development fifty years ago have made it economical within a few years? I think not.

Fifty years ago the needed knowledge of materials and fabrication was not available. More than that, the tools to develop this knowledge were not in existence. No industrial x-rays, no spectrographs, no arc welding, no stainless steels, no electric furnaces. Some of the metallic alloying elements we use today had not even been discovered.

What new tools and new knowledge do we need in order to build economical atomic-power plants? I don't know, but I am willing to bet that our engineers and scientists will find out in the decades to come!

Well, let's assume it is, say 1975, and that we can build and operate atomic-power plants at competitive costs. Can these be free from rigid government control? I think so!

Under present conditions, with practically all of the country's production of fissionable material going into bombs, and with such emphasis on secrecy, it is obvious that the government will retain complete control of all reactors. Even so, it could sell to utility companies any electricity generated, or even steam, or heat in some other form.

But I cannot conceive that present conditions will continue for very many years. There must be a limit to the useful size of a bomb stockpile. Our potential enemies will, in time, probably know as much about atomic energy as we do—possibly more! So the need for secrecy should disappear.

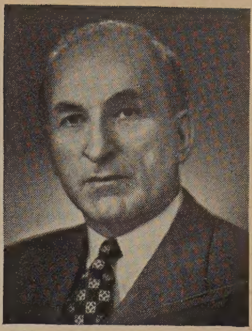
When atomic bombs become as common and widely spread as T.N.T. and other munitions, I see little chance for effective international control of atomic energy. If we are smart enough to find a means for preventing all war, then international as well as national control may become unnecessary.

So, in the reasonably near future, I visualize the opportunity for the government to discontinue entirely, or nearly so, its operations in this field, allowing private industry to forge ahead. I cannot forecast whether our government will wish to take advantage of this opportunity.

On the whole, for the long pull, I am optimistic about atomic energy in the power field. Today, and for a good many years to come, it need not be considered as a competitor of coal and oil. But utility executives should not forget it. They, and especially some of their engineers, should, insofar as possible, keep informed on progress in this field so that, at all times, they can give due consideration to this new source of energy. In my opinion the development will be evolutionary, rather than revolutionary, and atomic energy will only supplement and not supplant coal and oil as fuels.

REDUCING THE GENERATION OF WASTE: A COST-CUTTING TECHNIQUE

Reducing the generation of waste at every opportunity is both the individual and co-operative responsibility of everyone who has any part in producing today's manufactured products. Then there will be the minimum of waste to be salvaged



W E Casey

By W. E. CASEY
Manufacturing Policy Division
General Electric Company

THE meaning of salvage in modern industry has been expanded in recent years. The ordinary concept of securing the maximum return for materials which have been rendered temporarily unusable, for one reason or another, is thus made to include the idea of preventing the generation of waste through improved utilization of both productive and nonproductive materials.

Collection, segregation, preparation and disposition of scrap caused by normal processing (turnings, bar ends, skeletons, etc.), defective workmanship, accident, and obsolescence remain an essential part of the salvage department job, but to these has been added the necessity for joining forces with product design engineers, tool engineers, purchasing and manufacturing personnel in controlling the amount of scrap generated and in reconverting to usable form the greatest possible amount of the scrap which has been generated. This broad approach to the salvage problem has been, in effect, to make salvage everybody's business, and it has resulted in marked economies not only in material but also in direct labor and the indirect expense of manufacturing.

CO-OPERATIVE EFFORT

Increasing the utilization of materials as purchased requires that every factor affecting the part—its material, its design and its method of manufacture—be considered. The process is, by its very nature, a co-operative one and enlists the talents of engineering, methods, and production personnel.

The product design engineer has as his primary responsibility the development of product design and the preparation of engineering specifications for release to the factory. He must determine the best way to combine all the desirable functional characteristics of the product into a presentable and commercially acceptable design. At the same time, he must design the various individual parts so that the product can be made at the lowest possible manufacturing cost consistent with the established standards of quality. It is in the latter phase of his work particularly that salvage becomes the design engineer's business. Since it is his responsibility to specify the form and substance of the individual parts as well as of the end product, he occupies a strategic position in the campaign to eliminate waste by preventing its generation. His plan of attack may be as simple as liberalizing unnecessarily close tolerances which are causing a high percentage of scrap loss in manufacture, or changing "special" parts in his design to "standard" parts that can be obtained at a very much lower cost.

STANDARDIZATION

The simplicity of the standardization approach does not in any way minimize its importance in the program to conserve materials. The effectiveness of standardization is especially apparent in job-shop operations in which new models are added over a period of years to meet the requirements of certain customers. Obviously it is essential for design to meet customer requirements; but frequently such new models differ in only a very small degree from models already in production. This results in additional engineering drawings, more purchase orders for smaller lots of material, and more frequent set-up changes with short production runs, all of which tend to generate waste, not only in materials but also in time and effort. The design engineer can do much to correct these conditions by reviewing existing models for the purpose of consolidating models and features of models so that requirements can be covered by as few models as possible.

The standardization program of a manufacturer of steel cabinets is illustrative of what design engineering can contribute to the technique of salvage. In this instance, the product line consisted of 73 different models which provided a choice of 6 heights, 16 widths and 4 depths, some dimensions of which varied as little as one inch. Since dimensional differences of several inches had little effect on the installation and use of this equipment it was possible to standardize a line consisting of 12 models, which offered a variety of 2 heights, 3 widths and 2 depths. With standardized outside dimensions, the next step was the redesign of the component parts. The standardization by model made this a relatively simple task. As there were only two heights and two depths, only 4 separate side panels were required to assemble the line of 12 models. Further, since only two heights were involved, only two corner pieces were required for assembling the entire line. The program was carried through to include a review of the hardware

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This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

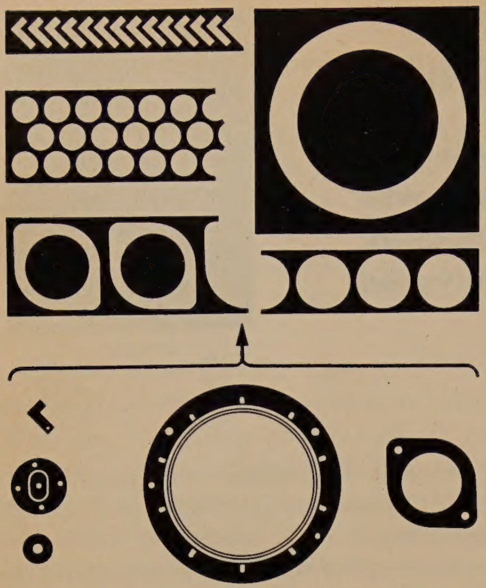


Fig. 1. Typical strip skeletons of sheet material remaining after the production of a group of pieces (also shown) by individual single-operation punch presses. Material utilization by this arrangement was 36 percent

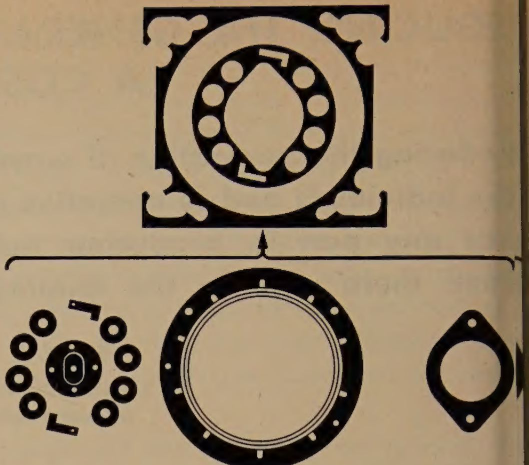


Fig. 2. Skeletons of material remaining after production of the same parts as in Fig. 1, but by a strip layout for a six-station progressive die in the punch-press operation. Material utilization by this arrangement, 60 percent

required, and the 12 different door handles previously specified for the 73 original models were reduced to one vendor's standard for all of the 12 redesigned models. In all the number of parts required to manufacture a representative line of cabinets was reduced from 156 to 43.

EFFECTIVE PLANNING

As was pointed out earlier, the attack on waste is a co-operative one and one of the most effective combinations is made up of the design engineer and the tool engineer. Working together, these two can eliminate waste by developing designs that lend themselves to the most economical method of manufacture. The design engineer must incorporate the essentials of function and structure, while the tool engineer, with his responsibility for providing the special tooling, the general production facilities, and the planning instructions necessary to manufacture the product, can, during design development, propose modifications in the structural design which will make possible the use of faster, simpler, and more economical manufacturing processes.

An example of this team approach was found in developing a major design change in a product that provided the solution to a critical manufacturing problem. Much of the difficulty that had been encountered in the manufacture of the product stemmed from a design which specified the use of grey iron castings for structural members. One of the castings served as the upper member of the unit frame and also as the housing for the operating controls of the equipment. This construction gave the product strength far in excess of what its usage required and added a great deal of unnecessary and undesirable weight. The machining operations on the casting were slow and expensive and the portion of the casting that was exposed to view required meticulous hand finishing operations prior to final painting.

The product was made the subject of a joint study by a team of design engineers and tool engineers, who developed a new design which retained all the functional features of the original and at the same time was much easier to manufacture. The dual-function casting was replaced by two separate pieces, one of sheet metal to serve as the structural member, the other a plastic cover to accommodate the controls. The use of sheet metal permitted replacement of expensive milling and drilling operations with lower-cost press work and, with the use of the plastic cover, eliminated the need for high-cost hand finishing. Although the substitution of sheet metal increased the amount of scrap generated and involved a higher cost per pound for material, the reduced weight of required metal permitted a greatly lower material cost per unit. In conjunction with the plastic cover, the sheet metal offered further the advantage of eliminating the need for a dial case, as the instruments could be flush-mounted from the rear.

IMPROVED TECHNIQUE

The application of improved techniques in handling the work at the machine provides the tool engineer with wide opportunities for salvaging both material and labor. In many instances sheet metal parts are still being made by methods that result in the generation of an excessive amount of waste material. Where hand-fed presses not equipped with feed stops are employed, the amount of material fed at each press stroke is dependent on the judgment of the operator, and even the most experienced will, at times, under- or over-feed strip lengths with an attendant loss of good material. Measured feed against positive stops, on the other hand, makes certain that only the predetermined off-fall will result. Scrap-cutting attachments on the presses free the operator of the task of disposing of the strip skeleton which would have had to undergo further handling and preparation before it could command the most favorable price in the scrap-metal market.

Examination of strip skeletons often indicates to the tool engineer how the improved nesting of parts will contribute to the salvaging of good material. The skeletons shown in Fig. 1 remained after the manufacture of a group of parts on individual single-operation presses. All the parts were made from steel strips that were similar, but not identical, in quality and gage. In the large ring, the material loss amounted to 64 percent of the amount purchased. Since the quality of the steel for the ring was equal or superior to that specified for the other parts, and the variations in gage were so slight that they could be ignored, the opportunity existed for using the scrap from the ring for the manufacture of some of the smaller parts. After some experimentation, the strip layout shown in FIG. 2 was developed. Using a six-station progressive die, it was possible to get from one strip all the parts which had formerly been obtained from 6 strips, and material utilization of the one strip was increased from 36 percent to 60 percent.

In another instance, as shown in FIGS. 3 and 4, the tool engineer was able to effect a 30-percent reduction in the scrap generated simply by changing the orientation of the die.

CONSERVATION OF VALUABLE MATERIALS

The salvage activities of the tool engineer are not restricted to reducing the amount of productive materials required and limiting the quantity of scrap generated. In specifying the tooling, he not only must consider the savings in production time made possible by high-speed tooling, but he must also be constantly alert to the opportunities of conserving the valuable materials from which the tools themselves are made. While the salvage factor is, of course, not the strongest reason for its use, the appropriate application of Carboloy cemented carbide supports this program in several ways.

Insofar as single-point cutting tools and milling cutters are concerned, the use of tools with brazed or inserted Carboloy tips on low-carbon steel shanks or bodies provides longer tool life and permits replacement of only the cutting tip when the tool is worn out. High-speed-steel tools, on the other hand, are one-piece; and once further regrinding is not feasible, and the tool worn beyond the point of salvage, the entire tool must be scrapped. This naturally involves the loss of a considerable amount of expensive material.

Similarly, the use of Carboloy is conducive to material conservation in tool maintenance. It is still customary in many plants for the operators to re-grind their own high-speed-steel tools at grinding wheels located throughout the machining area. During these "touching up" operations, a varying amount of the steel will be ground away. While the loss from any one tool may be slight, the great number of tools so touched up every day makes the aggregate loss in high speed steel considerable. This loss is eliminated where Carboloy tools are used, because all Carboloy tools must be ground in a central tool crib under carefully controlled conditions.

The introduction of Carboloy for blanking and drawing dies also tends to reduce scrap losses. These dies can be run 10 to 20 times longer between regrinding than steel dies. The frequency of regrind set-ups is thereby lessened and the material consumed in set-ups is proportionately less. Furthermore, the development of burrs is much slower and more gradual than is the case when steel dies are used, and the chances of producing punchings of sub-standard quality are thus decreased.

DISCRIMINATING PURCHASE

The purchasing department also shares part of the salvage job. This responsibility extends through practically every phase of its activities in securing adequate quantities of materials at the lowest cost consistent with established quality standards. In consultation with the design engineer, buyers draw from their knowledge of availability and cost of materials to suggest those which, by reason of their particular suitability will minimize waste generation and promote greater over-all economy. In collaboration with the processing specialists, buyers contribute their knowledge of vendors' facilities and capacities in deciding which parts can be most economically purchased and which should be the product of in-plant manufacture. The buyers contribute further to waste prevention by working with the process engineers in the development of slit widths of strip and sheet stock such that extra charges will not be incurred and of material multiples such that excessive losses will not occur in coil and bar-ends. Similarly, the selection of bar sizes as near as possible to the finished dimensions will reduce the amount of material to be removed in machining operations. The details of schedules worked out with the suppliers of materials are also factors that contribute to cutting down material losses because the hazards of deterioration and

(Continued on next page)

Fig. 3. Diagram that is typical of one die arrangement for producing a given punched part

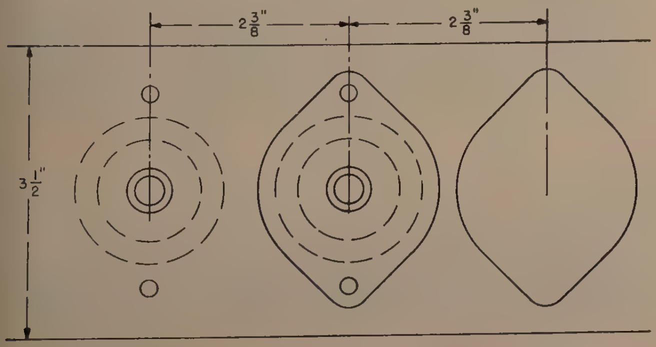
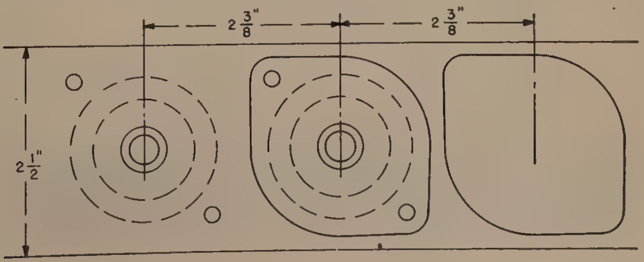


Fig. 4. Diagram of reoriented die arrangement for producing the part shown in Fig. 3 from a narrower strip, thus effecting a 30 percent reduction in scrap material



DESIGN ENGINEERS

CAN YOU USE
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Thyrite may be the answer to some of your circuit problems. It is a silicon-carbide ceramic material, dense and mechanically strong, having nonlinear resistance characteristics—the resistance varying as a power of the applied voltage. Its resistance characteristic is stable, and substantially independent of polarity or frequency. Thyrite® has been used for many years in important applications, including electronic. It can be produced in various shapes and sizes (those which can be successfully molded).

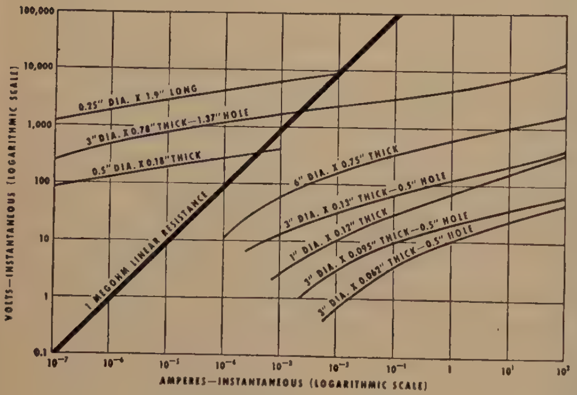
Some of its MANY APPLICATIONS

For protective purposes (to limit voltage surges).

As a stabilizing influence on circuits supplied by rectifiers.

As a potentiometer. (The division of voltage can be made substantially independent of load current.)

For the control of voltage-selective circuits, either independent of or in combination with electronic devices.



Typical volt-ampere characteristics of Thyrite resistors of several resistance levels and power ratings. Note that the nonlinear voltage-current characteristic extends over an extremely wide current range. Compare it with the characteristic (heavy line) of a 1-megohm linear resistor. Apparatus Dept., General Electric Company, Schenectady 5, N. Y.

Contact your nearest G-E office for additional data or address Transformer & Allied Product Divisions, General Electric Company, Pittsfield, Mass.

GENERAL ELECTRIC

(Continued from preceding page)

obsolescence can be overcome to a great extent at this time by scheduling deliveries of the most valuable materials to coincide with the time of their use.

RECLAMATION

Purchasing is equally concerned with the utilization made of the materials after they have been brought into the plant. A case in point is the care and use of manufacturing supplies. Towels, gloves, and perishable tools, for example, may be either the cause for excessive waste or a real opportunity for cost cutting through salvage activity. Wiping towels, because of their uniform size, can be rationed out and collected under a system of tool checks that permits as close control as that exerted over any tool. This provides the foundation for establishing an arrangement whereby wiping towels can be obtained from outside suppliers on a rental basis and collected for washing when soiled. Much extra usage is salvaged from the towels and, because of the close check kept, losses are held to a minimum. In much the same way, a recent study of glove usage is resulting in greatly reduced expenses for gloves. When gloves can be had for the taking, they frequently disappear at a rapid rate to find their way into home workshops and tool sheds. Close analysis of glove needs, standardization of purchases, and control over issuance and collection are the principal steps in establishing a glove salvage program. When these preliminary steps have been taken, it is possible to complete arrangements for the cleaning and repairing of gloves which results in prolonging their useful life.

Comparable success has been achieved in increasing the percent of utilization of the paint purchased for certain applications. Where the design of the parts is suitable, electrostatic paint spray installations have cut to a minimum the amount of spray which misses the work. The spray entering the charged field is drawn to the work, leaving an evenly spread coating of uniform thickness. In other instances, it has proved profitable to reclaim the overspray paint that is precipitated by the water curtain in water-wash spray booths. Paint equal in quality to the original can be reclaimed from the sludge at a cost of only about a dollar a gallon.

Production personnel likewise are able to make a positive contribution to reduced material cost under this new and broader concept of salvage. Careful regulation of work-in-process inventory maintains the optimum amount of material in flow and reduces the chances for obsolescence and deterioration. In this way, no large banks of semifinished material are generated that would increase the hazard of loss when changes in design must be incorporated.

Some of the salvage contributions of the so-called service functions have been cited, and attention is turned to the role of the manufacturing foreman in preventing the generation of scrap. Unquestionably the prime requisite in reducing scrap is through training nd instruction of the operator on the job he is to perorm. Thereafter, it is a matter of frequent checks of he quality of work being produced in conjunction with hecks of the condition of the machines, the tooling, nd the set-up. The inspector can only tell that the art he checks is sub-standard; the manufacturing man ust anticipate possible causes of scrap and take the teps necessary to prevent it.

CRAP DISPOSAL

In the final analysis, however, no matter how intense drive is made to control scrap generation, inevitably here will be some material which can no longer be used nd it must be disposed of as economically as possible nd the best price obtained for it. This requires that he scrap be collected, segregated, and prepared for ale, each step being a highly specialized process, but ll closely interrelated. The market for scrap must be tudied, just as the market for any other product, and ecisions of collection and segregation based on the arket demand.

Obviously the place to begin segregation is at the oint of generation; but since problems of collection do ot always make this feasible, some compromise must e made. Any unnecessary admixture of metals proves ostly, however, because, in general, an admixture sually brings less than the market price for the least valuable constituent. When it is borne in mind that there are more than seventy grades of ferrous scrap and iterally hundreds of grades of nonferrous scrap, the complexities of the segregation problem are most apparent. Preparation refers principally to improving the physical and dimensional characteristics of the material. Aware that better segregation and preparation will pay dividends, the modern salvage departments have installed special equipment for such operations as cutting, crushing, and separating, and for baling and briquetting materials so that the scrap will be in a more desirable form and therefore command a higher price.

Salvage, like all other segments of industry, is a dynamic process, undergoing constant change. It is truly worthy of unending investigation and everyone connected with manufacturing operations must realize that salvage is everybody's business.

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"stub" position crimps are possible with
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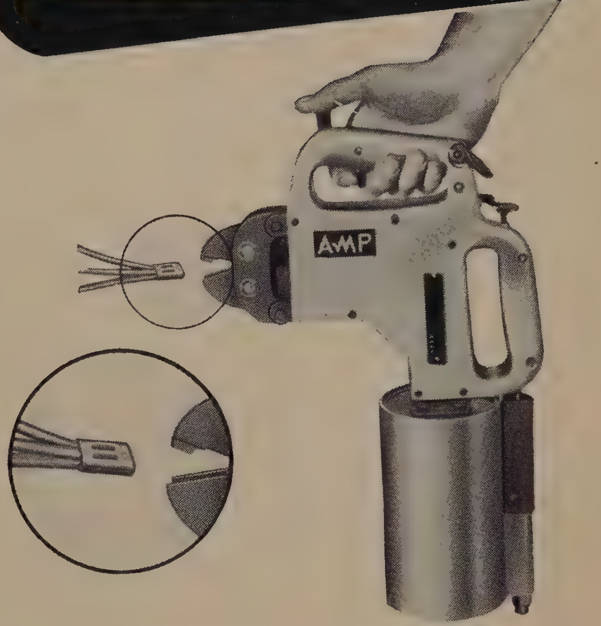

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This sturdy AMP tool features interchangeable crimping heads for either conventional "side position" or novel "end" position crimping, as well as a double set of handles and triggers. A suspension loop enables tool to be supported from above. Air cylinder is constructed of seamless tool steel—safety factor 300%. Toggle action jaws insure complete crimping cycle. Operates from standard shop outlets of 85 p.s.i.

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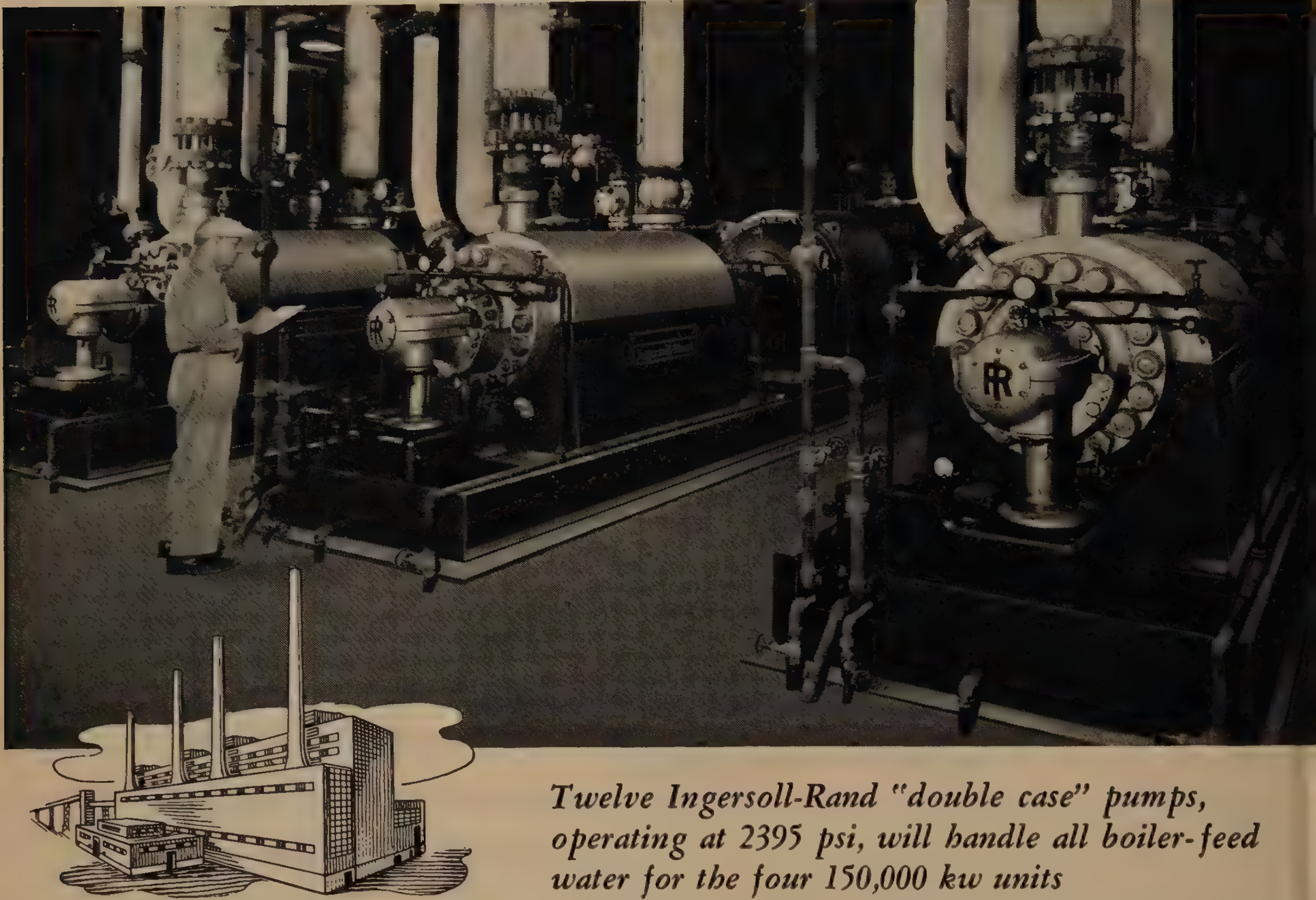
NEW PHILIP SPORN STATION TO INSTALL 24,000 HP OF I-R BOILER-FEED PUMPS



Twelve Ingersoll-Rand "double case" pumps, operating at 2395 psi, will handle all boiler-feed water for the four 150,000 kw units

This new high-pressure steam generating plant, named in honor of Philip Sporn, president of the American Gas and Electric Company, will serve the company's vast interconnected system in the seven states of Michigan, Indiana, Ohio, Virginia, West Virginia, Kentucky, and Tennessee. Designed by and constructed under supervision of the American Gas and Electric Service Corporation, it will eventually make available 900,000 kw of net output capability to meet the system's rapidly increasing demands for electric power.

The new Philip Sporn Station of the American Gas and Electric Company System, near New Haven, West Virginia, represents the last word in steam plant design. The first generating unit with a net output capability of 150,000 kw, went into commercial operation in January 1950. Three additional units, which are already under construction, will bring the plant net output capability to 600,000 kw.

Each of these four generating units will be served by three Ingersoll-Rand Class CHTA, 11-stage, "double case" pumps—two for full load requirements, and the third for stand-by service. Three of these feed pumps are shown above, direct connected to 2000 hp, 3570 rpm motors. Each pump is designed to handle 1100 gallons per minute, at 2395 psi and 304° F.

Here, as in all high-pressure steam plants, the accent is on *dependability and continuity of service*. And Ingersoll-Rand boiler-feed pumps have repeatedly proved their ability to stay on the job year after year under the most severe operation conditions. That's why they're *first choice* for really high pressure service.

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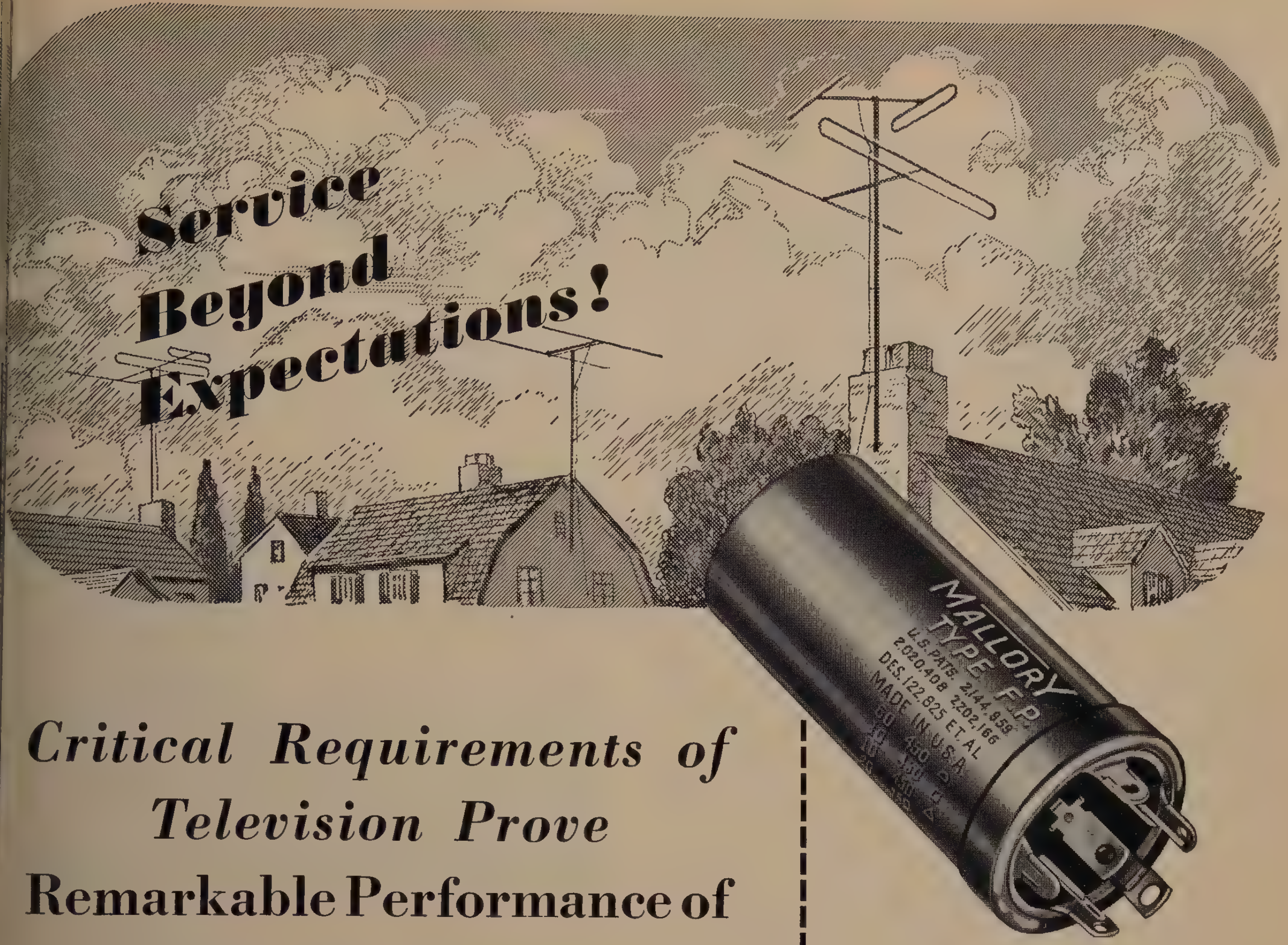

Critical Requirements of Television Prove Remarkable Performance of Mallory FP Capacitors!

There can be no more convincing proof of superiority than the performance records hung up by Mallory FP Capacitors in the demanding field of television service.

In one case, an outstanding television manufacturer kept detailed records of field failures of component parts over a six month period . . . found only six Mallory failures, with nearly 400,000 FP Capacitors in service!

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That's why so many leading manufacturers insist on Mallory Capacitors that have set the pace in the industry for years. That's why you should specify Mallory, at no premium in price, for any application that demands continuous, trouble-free performance.

MALLORY FP CAPACITORS

Mallory FP Capacitors are designed to operate continuously at 85° C—and are famous for their long *shelf life.* Write for your copy of the Mallory FP Capacitor data folder.

FP is the type designation of the Mallory-developed electrolytic capacitor having the characteristic design pictured and famous throughout the industry for dependable performance.

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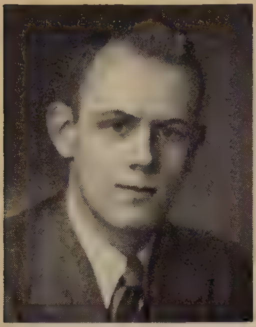
QUALITY CONTROL: A NEW FIELD FOR INSTRUMENTATIO



T. R. Hand

The quality control indicator, as applied in gaging and inspection in repetitive manufacture, is held the biggest step forward in scientific quality control since the beginning of the science itself

By T. R. HAND and C. J. FALK
Special Products Division General Engineering and Consulting Laboratory
General Electric Company

IN INDUSTRIAL manufacturing, every production line will produce some rejects. To keep those rejects within economic limits, a technique known as scientific quality control has been developed.

Scientific quality control employs control charts which are based on mathematical probabilities. With knowledge of past production history, it is possible to predict with a known degree of risk whether present production conditions are producing too high a reject rate. The method has often resulted in reducing reject losses in a manufacturing process from thirty to fifty percent.

QUALITY CONTROL IN THE PAST

Not until the second World War did it begin to be widely realized that scientific quality control enables a manufacturer to turn out a larger number of acceptable products for the same number of units produced. Since the war, competition has stimulated the use of quality control as a means of reducing scrap and rework expense, and improving production efficiency.

The information needed by quality-control engineers is:

(1). Total number of units produced
(2). Total number of units rejected by each test.

To process this information, control charts such as that in FIG. 1 are used. The average percent defective which has been found in recent production is used in determining the average percent defective expected. The horizontal dash line across the chart is calculated from the total daily production and previous reject history. When the reject level is above this line (the upper control limit), abnormal production troubles are present and should be corrected immediately. Reject level below the upper control limit indicates satisfactory production. The actual percent rejects are plotted and the points connected as shown.

Certain drawbacks of scientific quality control are immediately apparent. First, the time delay in collecting, processing, and applying the data may be hours or days. Abnormal conditions on the production line will not stop and wait for the statisticians to make computations. Rejects will continue to pile up. Second, justify the method, the resulting reduction in man facturing losses must more than pay for the man-hou necessary to collect and process the data. Third, t method is intricate and somewhat mysterious to o unfamiliar with it. For instance, the formula for t upper control limit is:

$$\mathrm{UCL}=\left(p+3\sqrt{\frac{p(1-p)}{n-1}}\right)\times 100$$

where UCL = upper control limit in percent
p = average fraction defective expected
n = total production

For these reasons, management has, in some case been reluctant to accept the idea of scientific qualit control in spite of the potential savings.

With scientific quality control, each inspector on production line makes a mark on a tally sheet ever time he rejects a unit. A separate tally sheet is provide for each test or characteristic which he is checkin At the end of a shift or at the end of the day, thes tally sheets are collected from all of the inspectors an tabulated by the quality-control engineers. Each tes is then individually analyzed to see whether that partic ular test is falling within the predetermined economi limits. If it is found that too many rejects have occurre and the upper control limit is exceeded, then the qua

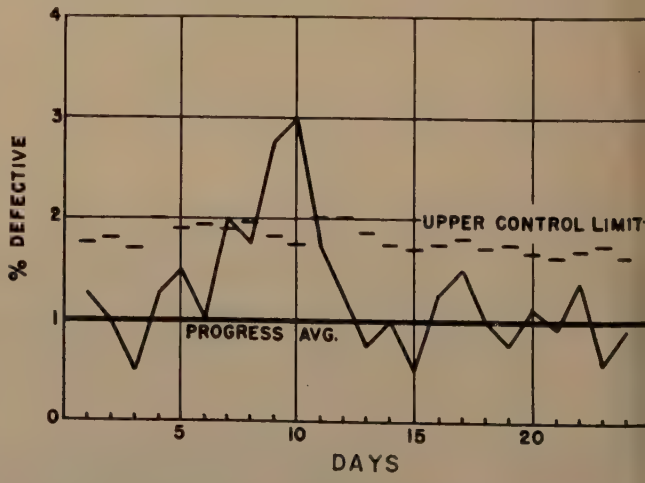


Fig. 1. Control chart of the type that is commonly used in the application of scientific quality control

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This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

y-control engineer informs the production supervisor at abnormal trouble is present and corrective action indicated. In the meantime, rejects are still being roduced.

A NEW APPROACH TO QUALITY CONTROL

The obvious answer to the problem of making ientific quality control most effective is to have no me delay between the rejection of a unit by the spector and the start of corrective action by the suervisor. The solution, however, was not so obvious. lore people could be used to make the computations t more frequent intervals, but an appreciable time elay would still be involved. Also, the additional manours make such a solution a prohibitive expense.

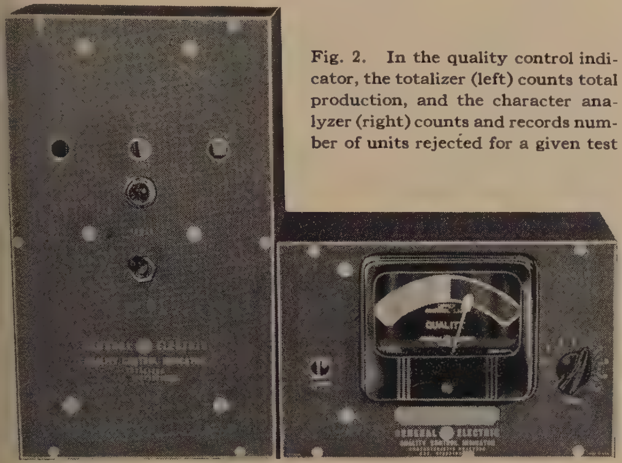


Fig. 2. In the quality control indicator, the totalizer (left) counts total production, and the character analyzer (right) counts and records number of units rejected for a given test

Quality-control engineers at General Electric's Erie Vorks had been using control charts for many years. They realized how much more effective statistical quality control could be if the information presented by ontrol charts was immediately available. Abnormal roduction troubles could then be investigated as soon as they occurred. Corrective action could be taken mmediately—not hours or days later. The problem resented by these quality-control engineers was the levelopment of a computer which would give instantaneous quality control.

The computer should count the rejects and total roduction on a production line and should analyze these counts immediately in accordance with the formula given earlier in this article. The Quality Control Indicator is the solution to this problem.

OPERATION OF THE QUALITY CONTROL INDICATOR

The quality control indicator (FIG. 2) consists of two basic units: a "totalizer," which counts total production; and a "characteristic analyzer," which counts the number of units rejected for a given test. The computer compares these counts according to the mathematical formula, and the result is indicated on the "quality" meter of the characteristic analyzer.

The quality meter shows instantly any abnormal difficulties in the production run for that test. When the needle moves from the green (left) half to the red (right), the quality meter indicates that some abnormal difficulty has arisen and that the process is "out of control."

CONSTRUCTION

The actual count of total production can be observed on dials seen through openings on the totalizer panel. The reject count can be observed in a similar manner on the characteristic analyzer. Power for the entire equipment is controlled by the power switch on the totalizer.

The mid-scale position on the quality meter is the upper control limit. The large scale, half green and half red, enables a supervisor to tell at a glance which test in a given series is above the upper control limit.

A level-selector knob gives a continuously variable range of reject levels from 0 to 10 percent. As few as one, or as many as ten, characteristic analyzers can be used with each totalizer. The totalizer and all associated characteristic analyzers are interconnected with cables and plugs in the back of the units.

It is possible to count thousands of units before resetting is necessary. By moving the power switch on the totalizer to the RESET position, the entire equipment is reset and again made ready for operation.

Circuit

The computer employs a bridge circuit, as shown schematically in FIG. 3. A d-c voltage is applied across two slide-wire potentiometers, *A* and *B*. Potentiometer *A* advances as the total units produced are registered in the equipment; potentiometer *B* advances as rejects are registered. To start operation, both potentiometers are at the zero position. A meter using a D'Arsonval movement is connected between the sliders of potentiometers *A* and *B*, and indicates the relative positions of the sliders. If the voltage at slider *B* is above or below that at slider *A*, the meter needle will deflect to the right or left of its zero center, giving a quantitative comparison between the total count and the number of units rejected. If, however, the potentiometer sliders are at points of equal voltage, the meter needle will not deflect from its zero center; this indicates that the ratio of rejects to production is running exactly on the upper control limit.

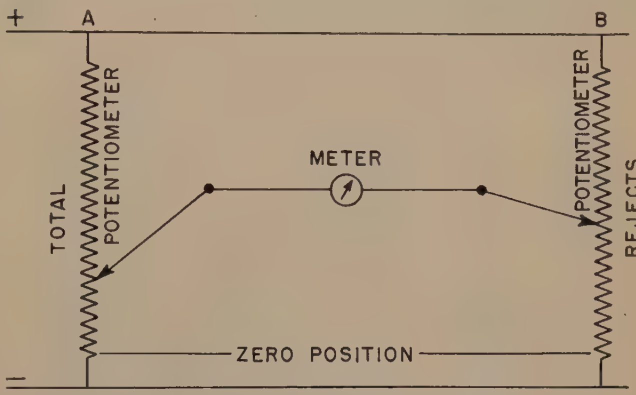


Fig. 3. Schematic diagram of the bridge circuit of the computer, consisting of two slide-wire potentiometers

The actual basic circuit used in the equipment is shown in simplified form in Fig. 4. This is a modification of Fig. 3 in that the reject-level potentiometer is added at *C*. Fig. 4 also schematically shows which portions of the circuit are in the totalizer and the characteristic-analyzer units respectively. The totalizer incorporates a d-c power supply and a linear slide-wire potentiometer. The latter consists of a telephone stepping switch with resistors mounted across the switch points. The characteristic analyzer incorporates (1) the quality meter, (2) the reject level selector, and (3) potentiometer *B*. The quality meter shows whether production is running above or below the upper control limit. The reject-level selector is a standard wire-wound potentiometer by which the predetermined level is set.

Potentiometer *B* is a nonlinear potentiometer that consists of a telephone stepping switch and resistors which bridge its contacts and which have such values as to make the meter conform to the curve shown in Fig. 5. Therefore, the quality meter will read in accordance with the formula for the upper control limit

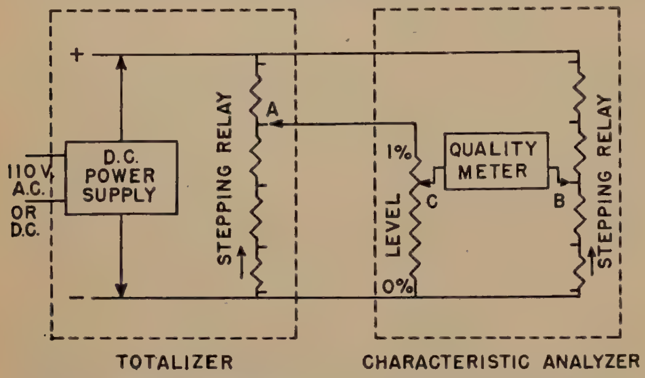


Fig. 4. Diagram of connections for the bridge circuit, with a third potentiometer at *C* to set the reject level

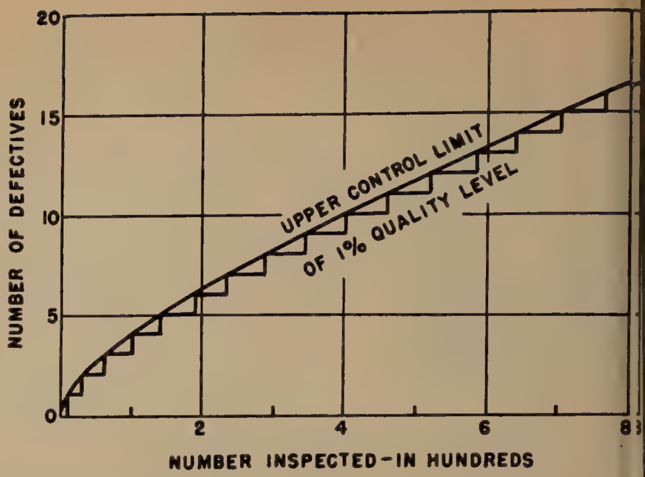
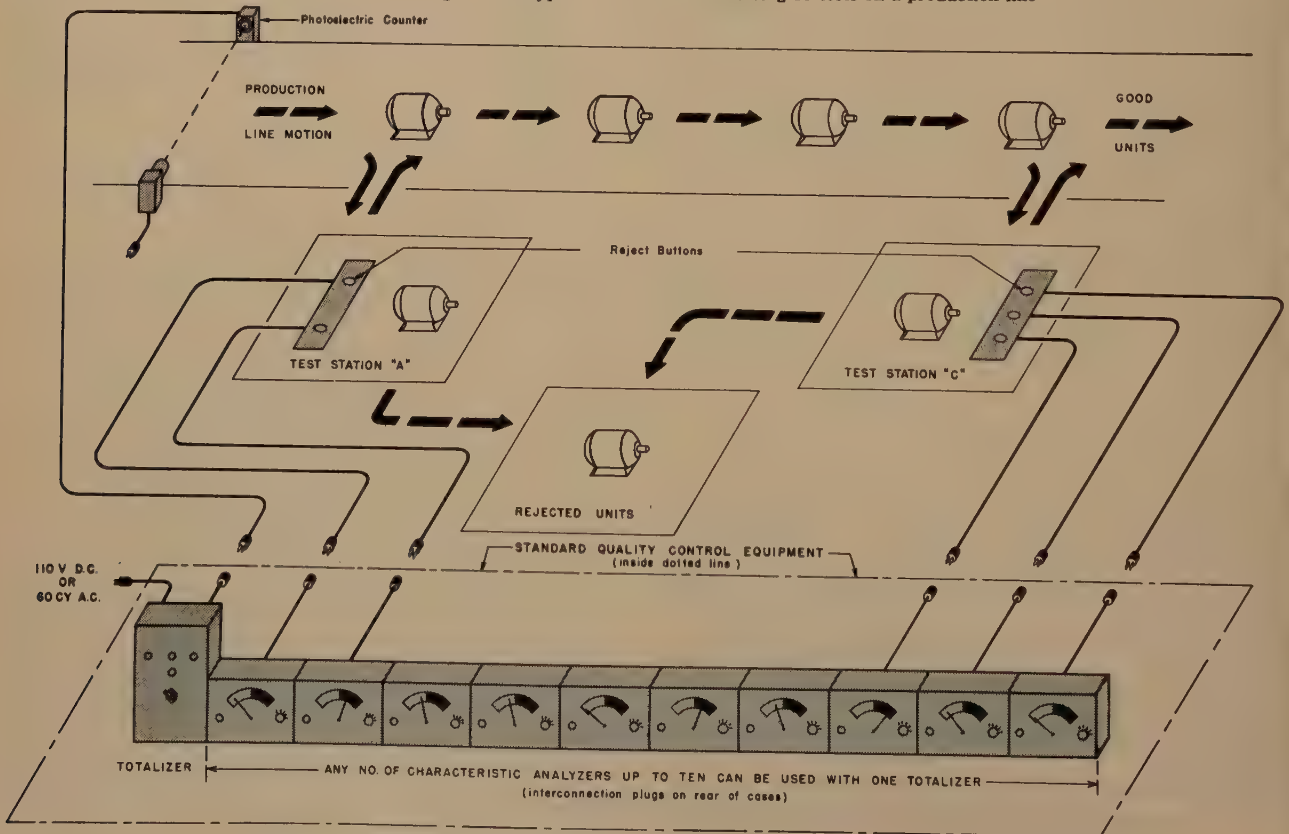


Fig. 5. Curve showing step sequence by which the meter indications s
correspond to the upper control limit

TYPICAL INSTALLATION

A typical installation of the quality control indicato is shown schematically in Fig. 6. The total number o units moving along the production line are counted b a photoelectric counter. This counter is connected to th quality control indicator to actuate the counter of th totalizer unit. At Test Station *A* the production unit are removed from the line and inspected for two different characteristics. If the unit is good it is put back o the production line. If the unit is defective and fails t pass one or both tests at Station *A*, it is set aside an the inspector at the station presses the proper rejec button. The two reject buttons at Test Station *A*

Fig. 6. Schematic diagram of a typical installation monitoring 10 tests on a production line


Photoelectric Counter
PRODUCTION LINE MOTION
GOOD UNITS
Reject Buttons
TEST STATION "A"
TEST STATION "C"
REJECTED UNITS
STANDARD QUALITY CONTROL EQUIPMENT (inside dotted line)
110 V D.C. OR 60 CY A.C.
TOTALIZER
ANY NO. OF CHARACTERISTIC ANALYZERS UP TO TEN CAN BE USED WITH ONE TOTALIZER
(interconnection plugs on rear of cases)

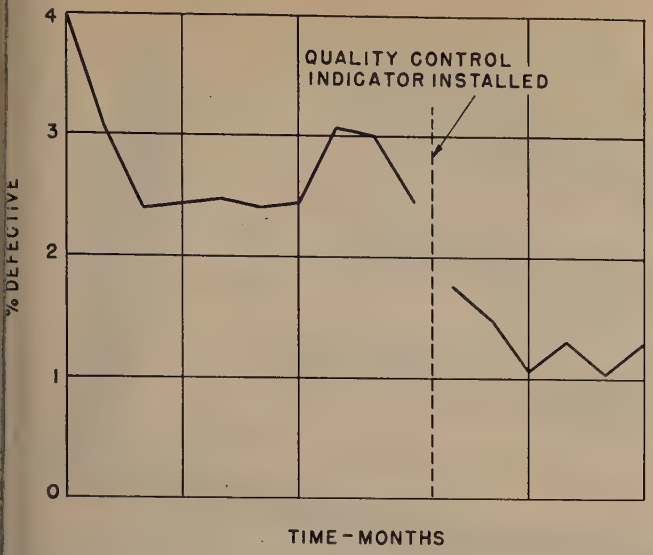


Fig. 7. Chart record showing the decrease in rejects following installation of the quality control indicator

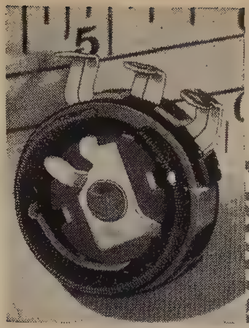
ctuate the corresponding two characteristic analyzers f the quality control indicator. The quality meter of ach analyzer shows instantly whether production is unning above or below the allowable reject level for hat particular test.

Test Station *C* is located a little further along the roduction line. Here the production units are again emoved and inspected for three additional tests. The umber of units rejected for the tests performed at this oint are registered in the associated characteristic nalyzers of the quality control indicator. As at Station A, the inspector has a separate reject button for each est being checked.

Using the quality control indicator, production supervisors know instantly when an excessive number of the units produced are being rejected. Prompt corrective ction can be taken. An immediate investigation of the production line and assembly points will allow the supervisor to quickly detect the difficulty causing the excessive rejects. Perhaps a die or a machine has become worn, causing some assemblies to be out of tolerance and not acceptable. The die can be replaced immediately or the cause of the trouble eliminated.

At General Electric's Erie Works, where refrigerators are made, a 60-percent reduction in rejects followed installation of the quality control indicator on a compressor assembly line. On this line, monitoring only five tests, more than $10,000 was saved the first year by reduction of scrap and rework expense. Greater efficiency also resulted, since a production supervisor ould more easily direct his efforts where they were eeded. Much closer quality control was achieved, as indicated by Fig. 7, and the customary rise in rejects uring the vacation period did not occur after the quality control indicators were installed.

As a result of this successful installation, ten other roduction lines, covering over 60 tests, are being monitored with quality control indicators at this plant. Quality-control engineers using the computer have alled it the biggest step forward in scientific quality ontrol since the beginning of quality control itself.



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1 to 10,000 ohms. Standard tolerance, within 10% plus/minus.

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Power rating: 2 watts average.

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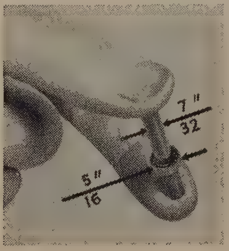

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GENERAL ELECTRIC

687-36

NEW LOW-VOLTAGE POWER FUSE OF HIGH INTERRUPTING CAPACITY

Requirements imposed by the severity of short-circuit currents possible in networks, industrial circuits, station auxiliaries, and on shipboard are met in an unusual new cartridge fuse that can be applied in the same way as conventional cartridge fuses

By C. L. SCHUCK
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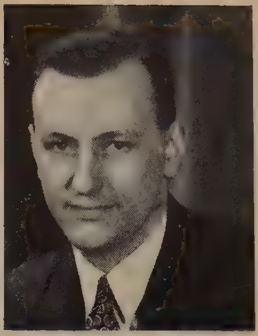
General Electric Company, Philadelphia, Pa.



C. L. Schuck

A NEED exists for low-voltage fuses having much higher short-circuit interrupting capacity than that of cartridge fuses commonly used.

Cartridge fuses for circuits of 600 volts and less have been used in the United States for many years, principally in low-burden branch circuits where available fault currents were relatively low. They are produced by numerous manufacturers, and practically all makes satisfy the National Electrical Code through compliance with the "Standard for Fuses" of Underwriters' Laboratories, Inc.(1)

In the matter of short-circuit interrupting ability, the "Standard for Fuses" includes a d-c test with 10,000 amp available, the rate of rise of the U. L. New York City testing circuit being approximately 2,000,000 amp per sec. While most applications of cartridge fuses are on a-c circuits, this d-c short-circuit test is, even today, the only criterion in use for determining the acceptability of fuses for application on either a-c or d-c circuits.

However, no direct inference is valid concerning the a-c short-circuit interrupting ability of a fuse which has passed this particular test. Table I shows limiting values of 60-cycle symmetrical available short-circuit current safely interrupted by members of a typical line of cartridge fuses, all of which passed the Underwriters' d-c 10,000-amp short-circuit acceptance test.(2) These were nonrenewable, nonindicating fuses.

Conversely, the a-c short-circuit interrupting ability demonstrated for a fuse is not a reliable indication of its ability to interrupt a d-c short circuit. Although some efforts have been made to establish a relation between a-c and d-c theoretically,(3) interruption tests on a circuit of the same type as that on which applications are intended are the only reliable basis for assigning interrupting ratings.

NATIONAL ELECTRICAL CODE CARTRIDGE FUSES

Cartridge fuses as manufactured in the United States, through standardization of dimensions and melting time-current and temperature-rise specifications of the "Standard for Fuses," have become extremely low-cost devices. Practically all makes employ a link of zinc wire or strip surrounded by a granular or powder filler (or merely air) and are enclosed in a rolled paper or fiber tube with brass or copper ferrules. Some makes incorporate special features such as time-lag in the melting characteristic, field renewability, etc.; but with one recent exception,(4) none of the numerous manufacturers, to the writer's knowledge, have published a-c or d-c interrupting ratings or d-c ratings other than those implied by Underwriters' Laboratories, Inc. approval based upon the 10,000-amp test value. In recent years, however, the progressive increase in the short-circuit currents possible on many networks, industrial circuits, station auxiliary, and shipboard circuits, has led to the demand for fuses actually having interrupting ability to cover these present day requirements, which are in many cases greatly in excess of 10,000 amp rms.

TABLE I

LIMITING VALUES OF 60-CYCLE A-C SHORT-CIRCUIT CURRENT SAFELY INTERRUPTED BY TYPICAL NEC CARTRIDGE FUSES

Voltage Rating	Ampere Rating	RMS Current Interrupted
250	15	20,000
	30	4,000
	60	5,000
	100	6,000
	200	15,000
	400	25,000
	600	30,000
600	15	20,000
	30	3,000
	60	3,000
	100	6,000
	200	15,000
	400	25,000
	600	30,000

EUROPEAN DEVELOPMENTS

In Europe, and principally in Great Britain and Germany, cartridge fuses of proved high interrupting capacity have been in use for some years. Their development evidently was spurred by efforts to conserve strategic materials, leading to their application in many cases where it is the American practice to use circuit breakers. Also, there do not appear to have been avail-

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This article was presented as a paper at the AIEE Great Lakes District Meeting at Jackson (Mich.), May 11-12, 1950.—Ed.

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

(1) Numbered references are listed at the end of the article.

able in Europe any counterparts of the mass-produced low-cost National Electrical Code fuses. Fuse development in England was accompanied by considerable research on the fuse-design factors and circuit parameters to determine their effect on interrupting ability, with the result that the high-capacity fuse designed according to these findings could justly be described by Gibson⁽⁵⁾ as "in its more advanced forms a reliable piece of apparatus with a precision performance."

The European high-capacity fuse for low-voltage service was of the same basic construction as the current limiting fuses already well established for high-voltage applications,⁽⁶⁾ having metallic links embedded in a granular, inert filler. The current-limiting manner of interruption resulting from this construction, when properly designed, minimized the energy dissipated in the fuse cartridge to the extent that external disturbance was eliminated and interrupting ratings could be assigned of 44,000 symmetrical rms amp for 660-volt circuits.

Although no standardization of dimensions had been found practical in Great Britain, "high-rupturing-capacity" fuses were developed to occupy minimum space; and for given ampere ratings these have diameters of the same order as American National Electrical Code fuses, but *shorter* cartridge lengths. The cartridges usually are made of heavy-walled ceramic material, having separate holes isolating the parallel element components and the resulting arcs formed during interruption. The holes are filled around the elements with granular quartz similar to that used in high-voltage current-limiting fuses (FIG. 1a). The transient pressure must still have constituted a considerable problem in view of the thickness of ceramic used—in German fuses for submarines, a substantial portion of the cartridge length was reinforced with a steel jacket, (FIG. 1b).

INTERRUPTING RATING

In commencing the development of a line of high-interrupting-capacity cartridge fuses suitable for manufacture here, it was realized that interrupting ability beyond the 44,000-rms amp rating of the British designs would be necessary to satisfy the requirements of many American industrial and shipboard circuits. A rating of 100,000 total rms amp (including d-c component) appeared to be the most satisfactory objective, so as to permit application on systems where circuit breakers of this rating are required in some circuits.⁽⁷⁾ The 100,000-rms amp rating in the case of a three-pole circuit breaker implies an available symmetrical short-circuit current of 80,000 rms amp, the factor accounting for the d-c component and average current among the phases being 1.25, as explained in the Appendix.

TUBE MATERIAL

Efforts toward obtaining the desired interrupting capacity were aided considerably by the availability from several American manufacturers of glass-cloth-base, heat-resistant resin-impregnated insulation in tube form. The strength and resilience of such tubes was found more than adequate to withstand the transient pressures occurring during interruption, with even more than the maximum element section usable as determined from time-current melting, and maximum temperature limits. Thus the problems associated with thick-walled ceramic tubes, reinforcement, etc. were avoided.

FILLER

Another asset available here for the development of fuses with higher interrupting capacity was a specially graded granular quartz filler developed for high-voltage current-limiting power fuses,⁽⁸⁾ where grain sizes are restricted to the range which provides maximum grain surface for withdrawing heat from the arcs, and at the same time provides the inter-granular air spaces required for the dispersal of the element metal.

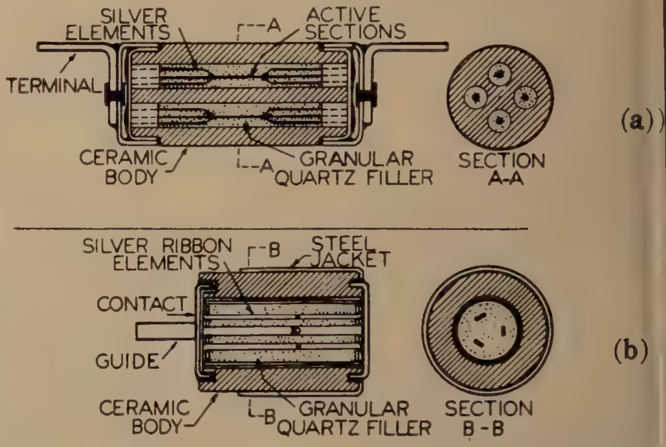

Fig. 1. Typical European designs for two cartridge fuses of high interrupting capacity
(a). British H.R.C. (high rupturing capacity) fuse
(b). German 350-volt 200-amp fuse for shipboard

ELEMENT DESIGN

In addition to advantages gained by the use of the woven-glass-base tube material and the improved filler, it was considered desirable to make use of any further advances that might result from improvements in the element proportions. As a general conclusion based on interrupting test results, it was found that substantial length was not required in the arc paths for the low circuit voltages involved. This differs from findings in high-voltage fuse developments.⁽⁹⁾ As circuit voltage was causing no particular hardship, the minimization through the use of short active element sections of the amount of metal which became involved in the arcs could be credited with much of the improvement obtained in interrupting ability.

The division of the element section required for a given ampere rating into a number of spaced parallel paths was found to aid in the prompt development of arc voltage, in limiting transient pressure in the cartridge, and thereby in further increasing the interrupting ability.

The degree of division of element section when carried sufficiently far was found to provide interrupting ability well above the 100,000-rms amp objective. Carried too far, extreme subdivision with the required spacing between elements calls for more fuse tube cross section than would be practical or economic. For adequate interrupting ability, with an acceptable pattern of element spacing, the number of parallel arc paths was found to be significant.

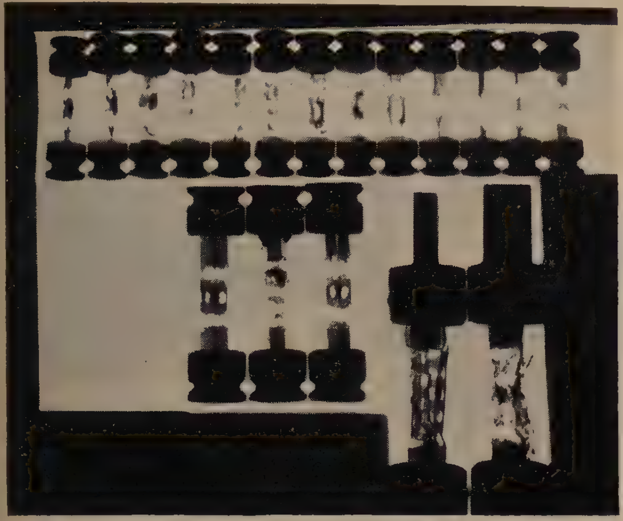

Fig. 2. X-ray photograph of unopened developmental fuse samples after short-circuit test

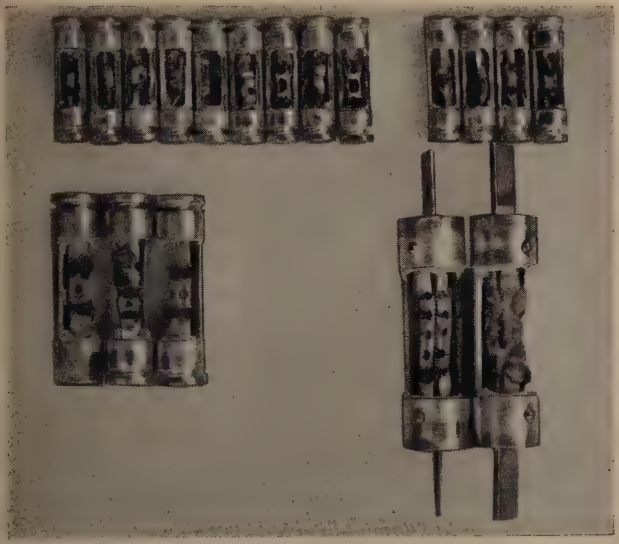

Fig. 3. Same fuse samples as in Fig. 2, with tubes cut away to show the "fulgurites" formed by the arc current

It was found that the number of rated amperes per single element necessary for the safe interruption of 100,000 rms amp should be substantially less than the amperes per element of European designs. This further reduction in the amount of element metal which becomes involved in any one arc path is the factor believed chiefly responsible for the greater interrupting ability found possible.

These factors, together with the spacing between arcs, and from any arc to the inner surface of the fuse tube, were investigated in a series of d-c short-circuit tests, using samples in which the element designs differed from one sample to the next by definite increments. As criteria of the difficulty with which the fuse sample opened the circuit, use was made of the temperature rise of the cartridge following the test, oscillograms, x-ray photographs, and ordinary photographs and examination of the fuse samples, with tube cut away to show the elements. FIG. 2 shows an x-ray photograph of typical unopened test samples following d-c short-circuit interruption tests. They show the degree of dispersion of element metal caused by the arcing. FIG. 3 is a photograph of the same samples cut away with excess quartz removed to expose the remains of the elements. By study of the size of "fulgurite" or slag formation where the arcs had fused the granular quartz filler, and the other means mentioned, the influence of each of the several factors was assessed, and conclusions were reached concerning:

(1). Number of elements (arcs in parallel)
(2). Number of reduced sections (arcs in series)
(3). Spacing between parallel arcs
(4). Spacing between arcs in series
(5). Spacing of any arc to inner wall of fuse tube
(6). Mass of terminals, and path to ferrules
(7). Type of filler.

From these observations followed the optimum dimensions and other data around which a line of high-capacity fuse elements could be designed.

A d-c circuit was employed for these tests in view of results of numerous earlier short-circuit tests in which a given fuse design performed well in interrupting an a-c circuit, but not so well in a d-c circuit. The salient factor making for greater severity in the d-c tests was evidently the sustained voltage, which caused arc current to persist, while in the a-c tests the falling voltage enabled the fuse to force current to zero at or before the first voltage zero following melting, sufficient deionization of the arc paths then taking place to prevent re-establishment of the arcs during the subsequent half-cycle or thereafter. FIG. 4 shows plots of oscillograms of an a-c and a d-c short-circuit test on

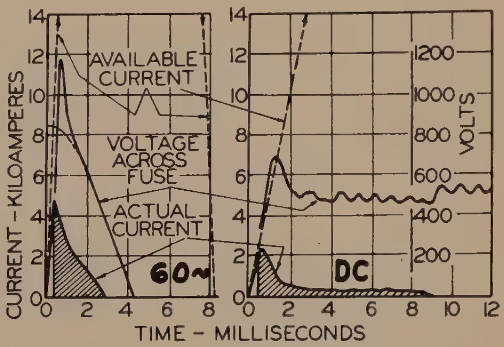

Fig. 4. Comparable a-c and d-c short-circuit tests. Sustained voltage prolongs arc current in d-c test

	60-cycle	d-c
Test Voltage	600 volts rms	525 volts
Available current	60,000 amp rms	30,000 amp
Melting time	0.0003 sec	0.0006 sec
Arcing time	0.0026 sec	0.0083 sec
Total time	0.0029 sec	0.0089 sec

developmental fuse samples of the same design, the arc current falling rapidly with decreasing voltage and ceasing before voltage zero in the 60-cycle a-c test, arcing time being 0.0026 sec, but persisting for 0.0083 sec (equivalent to a full half-cycle) in the d-c test. Once this was noted, efforts were directed toward so designing the elements as to combat the development of the trailing arc current on d-c tests, and its duration was employed as one of the criteria of good element design.

DIMENSIONS AND MELTING REQUIREMENTS

Based on the data accumulated, it appeared that it would be perfectly possible to make the line of high-interrupting-capacity cartridge fuses in the same cartridge sizes as conventional NEC fuses, even in the 250-volt 30-amp rating which appeared to be the "tightest" on the basis of the values in Table II.

TABLE II

AVAILABLE SPACE VS. REQUIRED CAPACITIES
NEC CARTRIDGE FUSES OF STANDARD DIMENSIONS

Voltage Rating	Ampere Rating	KVA	Internal Volume (Cu in.)	KVA per Cu in.
250	30	7.5	0.20	37.5
	60	15	0.70	21.4
	100	25	1.71	14.6
	200	50	4.39	11.4
600	30	18	1.31	13.7
	60	36	2.52	14.3
	100	60	2.82	21.2
	200	120	7.76	15.5

In order fully to meet the requirements of the "Standard for Fuses," elements had to be so designed as to melt within specified times at given percentages of overload current, and on normal current to generate heat at a rate sufficiently low so as not to overheat the fuses themselves nor connected devices such as knife switches, contactors, etc. The requirements are summarized in Table III.

"M" EFFECT

With respect to active element section required, the specifications are contradictory, requiring a large cross section for the 110-percent cool-running requirement, and a small cross section for the overload prompt-melting requirement. This problem was solved by use of the so-called "M" effect,(10) obtained by the addition of small globules of a tin-rich alloy to the active sections of the elements. On overload, the elevated temperature causes local alloying and diffusion of the silver element metal into the tin, the resulting alloy having both a higher resistance and a lower melting point than the silver alone. This permits the element to melt and separate at a current 30–35 percent lower than would be required if the element consisted simply of silver. Since this metallurgical process requires time for its accomplishment, the time-current curves of the fuses are not affected in the high-current short-time region, but do show displacement toward lower currents in the low-current long-time region. This is evident in the melting time-current curves shown in Fig. 5.

SHORT-CIRCUIT PERFORMANCE

With element sections adjusted to meet the specifications, and designed on the basis of the studies made after the earlier a-c and d-c short-circuit tests, acceptable short-circuit interrupting ability was demonstrated with fuses designed in standard cartridge sizes. Fig. 6 shows reproduction from oscillograms taken during a-c short circuit tests of the maximum ampere ratings in the four standard sizes: 30-, 60-, 100-, and 200-amp.

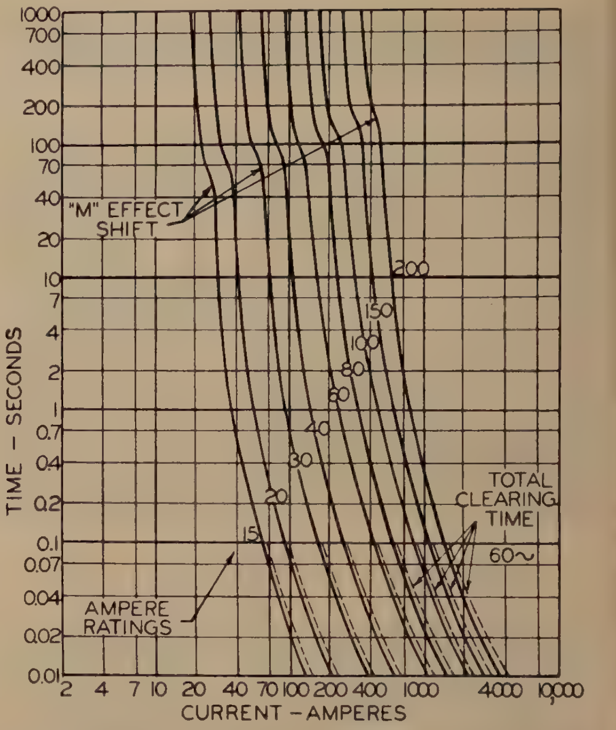

Fig. 5. Melting time-current curves. Improved overload protection results from "M" effect shift

TABLE III

TEMPERATURE RISE AND OVERLOAD MELTING REQUIREMENTS
OF THE UNDERWRITERS' LABORATORIES, INC. "STANDARD FOR FUSES"

Ampere Rating	Temperature Rise Requirement 110% of Rated Current	Overload Melting Requirements*	
		135% of Rating	200% of Rating
Up to 30	Max. Temp. rise of 50C on any part of the fuse.	1 Hour	2 Min.
31 to 60		1 Hour	4 Min.
61 to 100		2 Hours	6 Min.
101 to 200		2 Hours	8 Min.

* Fuse must operate within times listed.

These records, and many similar ones taken at different available short-circuit currents and angles of inception, fully substantiate an interrupting rating of 80,000 symmetrical or 120,000 total rms amp (see

Appendix). The records also furnish information useful in making applications. The extent of the current-limiting effect as a function of the ampere rating and the available short-circuit current can be obtained simply by measurement of the peak values of current passed (Fig. 6). These, plotted as a function of available current for each ampere rating, give the current-limiting curves of Fig. 7. Such test results as are shown in the current traces of Fig. 6 form the "anchor points" of the current-limiting curves of Fig. 7, and were checked and "smoothed" by calculation.(9 II) These maximum currents and their effective values and durations passed by given ampere ratings of fuses at available short-circuit currents of interest establish the short-time capacities required by series connected devices. Examples are: contactor coils (magnetic stress); the contacts themselves (thermal duty); switch contacts; connections; and other fuses or interrupters in co-ordinated protective schemes. Thus the *arcing time and current* along with the melting time and peak currents already mentioned, are of importance in making applications.

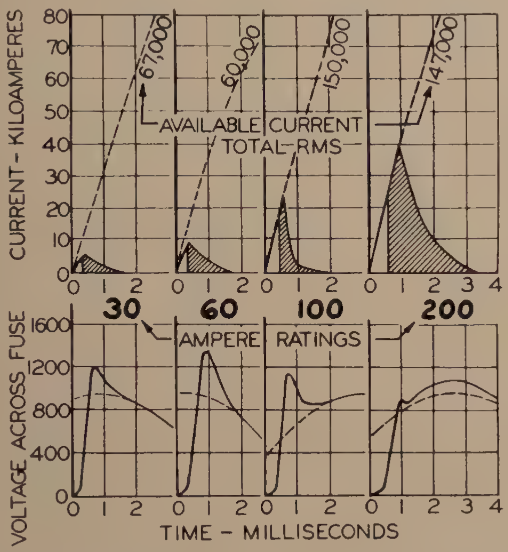

Fig. 6. Short-circuit tests at 660 volts rms, 60 cycle, of high-interrupting-capacity cartridge fuses.

Melting time-current areas: clear
Arcing time-current areas: shaded
Generated Voltage: dotted

"LET-THROUGH" CURRENT

Melting

As a measure of the current-time passed by a fuse in interrupting a fault, the heating effect or $\int i^2dt$ during both the melting and arcing periods should be evaluated. In the records shown in Fig. 6, the clear time-current areas are taken as melting periods, and the subsequent time-current areas (shaded) as arcing. Calculations indicate that the elements had sufficient heat developed in them by the passage of current to reach the melting point considerably before the times of the peak currents appearing on the oscillograms. This phenomenon was found to occur only with very high short-circuit currents, the peak currents and times for moderate available currents corresponding more closely to calculated values for melting. This indicates that current continues to rise, following melting on high available short-circuit current, until sufficient arc resistance has developed to cause the substantial reduction in current characteristic of the operation of current-limiting fuses.

With the available short-circuit current known as a function of time, a complete description of the instantaneous current vs. time leading up to melting can be calculated. However, a disparity between this mathematical description of the current during the melting period and the actual current is evident in the current traces in Fig. 6. The slope of the available current is not followed by the actual current, but is reduced by the resistance of the fuse. This effect is more evident in the lower current ratings, which have higher resistance. Assignment of melting time and current in the short-circuit tests in Fig. 6 was made using the slope of the actual current measured from the oscillograms rather than the slope of the theoretically available current.

Arcing

While current prior to melting depends almost entirely on the circuit constants and the character of the fault, the arc current following melting is influenced chiefly by the fuse—that is, by the shape of the arc voltage it produces. Although the shape and duration of arc current can be constructed by assuming values of arc voltage,(9 II) factual data on arc current can be obtained directly from oscillograms such as those plotted in Fig. 6. Arcing times are readily measured, and when added to the melting times for given ampere ratings, give the total clearing curves appearing as dashed lines at the bottom (high-current-fast-time) ends of the

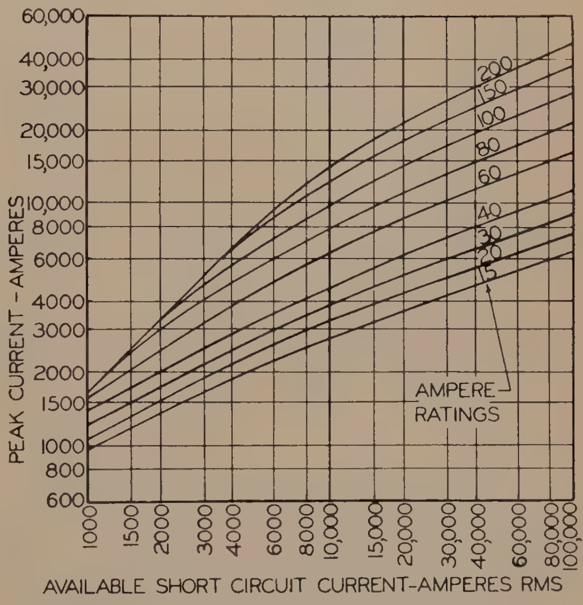

Fig. 7. Current-limiting curves for fuses considered in Figs. 5 and 6

curves in FIG. 5. The arcing $\int i^2dt$ can readily be evaluated provided the current has some simple form.

If arc current falls linearly from a value i_a to zero during a time Δt, it can be shown that

$$\int i^2dt=\frac{\Delta t}{3}\cdot i_a^2$$

More generally, if the arc current falls linearly from a value i_a to a value i_b during a time interval of Δt, it can be shown that

$$\int i^2dt=\frac{\Delta t}{3}\left\{i_a^2+i_ai_b+i_b^2\right\} \qquad (1)$$

By use of this expression, with time and current values measured from the oscillograms, the arcing $\int i^2dt$ was computed for the tests given in FIG. 6. These values (in ampere-squared-seconds) are listed in Table IV, together with $\int i^2dt$ required to cause melting on a short time-no heat loss basis. Their sum gives the total "let-through" current-time passed by a fuse of each ampere rating in interrupting a heavy short-circuit current.

This "let-through" $\int i^2dt$ must be tolerated by all devices connected in series with a given fuse. Depending on the resistance of the device, heat will be developed in it, and a rise in temperature will result. As a measure of the short-circuit protection afforded wire sizes commonly used with these ampere ratings in making motor branch circuit connections, the temperature rises resulting from the passage of the "let-through" $\int i^2dt$ were computed and are included in Table IV. These were calculated assuming no heat loss from the wire to its surrounding insulation during the short time interval of the "let-through."

TABLE IV

CURRENT-TIME PASSED BY HIGH-INTERRUPTING CAPACITY FUSES ON HIGH AVAILABLE SHORT CIRCUIT CURRENTS (FIG. 6), AND HEATING EFFECT ON CONNECTED WIRE

Ampere Rating	Melting $\int i^2dt$ +	Arcing $\int i^2dt$ =	"Let-through" $\int i^2dt$	Temperature Rise—C° Wire No. (or cir mil)	Rise	Wire No.	Rise
30	1,600	17,970	19,570	8	2.7°	10	6.8°
60	10,000	34,960	44,960	4	1.0°	6	2.4°
100	42,000	218,000	260,000	1	1.4°	3	3.5°
200	130,000	1,190,000	1,320,000	200,000	1.2°	0	4.3°

Another use that can be made of these melting and arcing $\int i^2dt$ values is the determination of suitable ampere ratings to use in co-ordinated protective schemes. In addition to so choosing ratings that the desired sequence operation is assured in the range of times (0.1 to 200 sec) in which co-ordination schemes are usually laid out (FIG. 5) it must also be ascertained whether the "protecting" fuse can complete the work of interrupting the circuit without damaging the element of the "protected" fuse through the range of available short-circuit current involved in the application. This in turn requires that the $\int i^2dt$ passed by the "protecting" fuse in both melting and arcing shall be less than the $\int i^2dt$ required to melt the "protected" fuse.

Calculations similar to those on which were based the $\int i^2dt$ values appearing in Table IV, were carried through to obtain the melting, arcing, and total $\int i^2dt$ at several levels of available short circuit current for all the ampere ratings appearing in the time-current curves of FIG. 5.

FUSE-TO-FUSE CO-ORDINATION

Comparisons of the resulting values yielded Table V, in which are listed the minimum ampere ratings to "back-up" the ampere ratings listed in the first column. The $\int i^2dt$ values and Table V are all based on 60-cycle circuits.

The ratings listed in Table V show that successive ampere ratings should not be used in series if selective operation is desired, except in a few cases with low available fault current. The more general case requires a ratio of 2:1 between the ampere ratings of "protected" and "protecting" fuses, and an even greater ratio with high short-circuit currents above 50,000 amp rms.

TABLE V

MINIMUM "BACK-UP" AMPERE RATINGS

Ampere Rating	Available Asymmetrical Short-circuit Current—rms 15,000	25,000	50,000	75,000	100,000
15	30	30	30	40	40
20	30	30	40	60	60
30	60	60	60	80	80
40	60	60	80	100	100
60	100	100	100	150	150
80	150	150	150	200	...
100	200	200	...	...	...

The same general method of comparing $\int i^2dt$ values can be used in many application problems concerned with short-time ratings of devices to be used in series with the fuses, and the application should be checked on this basis as well as with respect to sequence functioning.

OVERLOAD INTERRUPTION

Close attention to the factors making for good short-circuit-interrupting ability can lead to an element design which may or may not be inherently capable of interrupting the circuit safely in the event of an overload condition. In view of this, a series of overload tests were made at 60 cycles on the "final designs" of each rating, with the results shown in Table VI. Some of these tests were made outdoors in cold weather, and durations in these cases were longer than those given by the melting time-current curves in FIG. 5.

In these tests, particularly those in which the duration was more than ten minutes, all parts of the fuse had had ample time to assume temperatures, substantially as high as those obtainable at any value of overload current. With somewhat higher current, the duration is less and the fuse does not have time to get up to temperatures as high as the empirical optimum at 150–160 percent of the ampere rating. At less current, although the duration is longer, the wattage developed is less, and the fuse parts do not reach temperatures as high. The tests given in Table VI cover the region from 146 to 204 percent of rated current with most tests in the 150–160 percent region producing maximum temperature rises.

TABLE VI

OVERLOAD TEST DATA

Test No.	Voltage Rating	Ampere Rating	Test Current-Amp.	Test Duration	Recovery Voltage	Performance
1	250	30	44	13 min. 10 sec.	250	No Disturbance
2		60	92	4 min. 20 sec.	250	
3		100	185	13 min. 4 sec.	250	
4		200	348	14 min. 8 sec.	250	
5	600	30	49	12 min. 30 sec.	600	No Disturbance
6		60	101	10 min. 43 sec.	600	
7		100	200	4 min. 50 sec.	600	
8*		200	408	15 min. 24 sec.	600	

* Section of element of this rating subsequently reduced better to comply with the requirements of the "Standard for Fuses."

TRANSIENT RECOVERY VOLTAGE

The conversion of the fuse from a good conductor prior to and during melting, to an increasing resistance during arcing, causes a radical increase in the voltage drop across the fuse after peak current. During approximately the next 500 microseconds the voltage as measured across the fuse rises, reaching its crest at a time when current has been reduced substantially from its peak value, in many cases by as much as 50 percent. This relatively slow development of arc resistance and arc voltage results in a relatively lower peak voltage for these low-voltage fuses as compared to voltage peaks obtained with high-voltage current-limiting fuses, in which the arc resistance is caused to develop more rapidly, producing a voltage peak while current is still practically at its peak value.[11] Peak voltage values measured from the traces of Fig. 6, which are typical of records of many similar tests, average to 1190 volts, bearing a ratio to the crest of 600 volts of only 1.4. For present fuses, the ratio is 2 to 3.

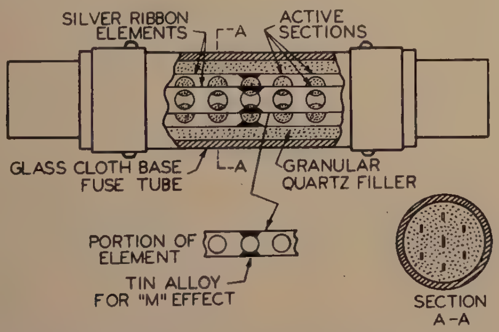

Fig. 8. Cut-away view and section of new 600-volt 100-amp high-interrupting-capacity cartridge fuse

LINE OF LOW-VOLTAGE POWER FUSES

Fig. 8 shows the construction for a typical rating of the new line of fuses designed according to the experience gained in the short-circuit and other tests described in the foregoing, and to comply with the requirements of the "Standard for Fuses." Examples of 600-volt rating of the four standard sizes (30-, 60-, 100-, and 200-amp) are shown in Fig. 9. While having the limiting dimensions of standard cartridge fuses, the mechanical design includes certain features which make possible the use of special clips that will not accept fuses of lesser interrupting capacity. These features consist of grooves in the ferrules of the ferrule-type fuses (Fig. 9), and a shorter body in conjunction with a projection at the base of the blade in the blade-type fuses.

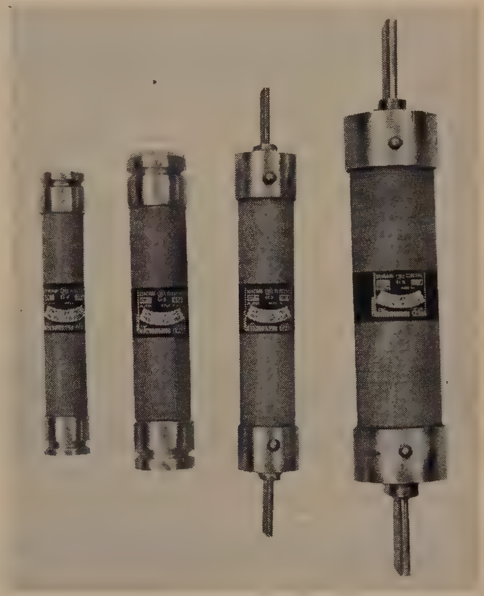

Fig. 9. Representative examples of new high-interrupting-capacity low-voltage power fuses. Shown (*left to righ*) are the 30-, 60-, 100-, and 200-amp sizes of 600-volt rating

CONCLUSIONS

(1). The need in the United States for fuses with high interrupting capacity for use on low-voltage circuits, now can be satisfied with specially designed fuses of the current-limiting type.

(2). A line of such fuses has been developed satisfying in every respect the "Standard for Fuses" of the Underwriters' Laboratories, Inc.

(a). Through compliance with standardized dimensions, fuses of the new line have the same physical sizes as conventional cartridge fuses.

(b). Through compliance with heating and melting requirements of the "Standard for Fuses," ratings

(Continued on following page)

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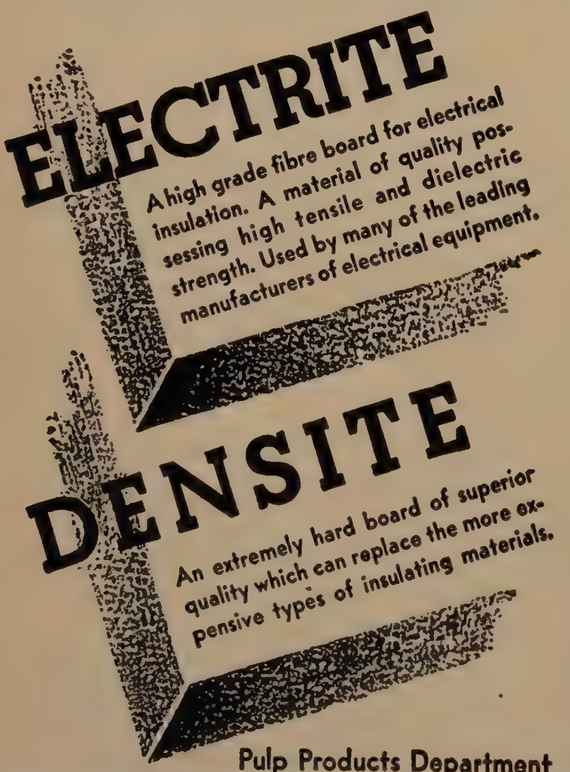
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NEW LOW-VOLTAGE POWER FUSE

(Continued from preceding page)

of the new line provide proved overload protection, and can therefore be applied, rating for (ampere) rating in the same way as conventional cartridge fuses.

(3). Interrupting ability in excess of 100,000 amp rms at 250 and 600 volts, 60 cycles, results from use of special materials and design factors established in controlled a-c and d-c short circuit tests.

(4). D-c interrupting ability, not completely determined through the range of rates of rise of current (inversely proportional to circuit inductance) occurring in d-c circuits, has also been demonstrated to be a considerable advance over the d-c interrupting capacities provided heretofore.

(5). Measurements from oscillograms taken during short-circuit tests make possible the evaluation of the heating effect—$\int i^2dt$ of current-time "let-through" by the fuse.

(6). Determination of the melting and arcing portions of the total "let-through" forms a basis for matching short-time ratings of other devices with the short-time fuse characteristics.

(7). Co-ordinated protective schemes in which members of such a series of current ratings of high-interrupting-capacity fuses are applied one ahead of (nearer the source) another, call for the use of ampere ratings having a ratio of 2:1 or greater for large available short-circuit currents.

(8). The transient recovery voltage associated with the current-limiting character of such a line of fuses, is relatively slow-rising and reaches peaks in the order of only 1200–1400 volts, easily tolerated by the insulation ordinarily used in 250- and 600-volt circuits, and an improvement in this respect also over voltage transsients produced by conventional cartridge fuses.

APPENDIX

Shown in FIG. 10 are the numerical relationships between the rms value of a symmetrical a-c short-circuit current, taken as 1.0, and the offset current resulting from various amounts of a d-c component added to the a-c current. In addition to the theoretical maximum of d-c present to the same amount as the peak value of a-c (in this case $=\sqrt{2}$) with total rms value 1.732, well accepted(12) factors of 1.6 for transmission circuits (momentary rating for circuit breakers—also total rms current for power fuses) and 1.25 for low-voltage circuits are shown. In the latter case, the maximum rms current possible in one phase would be 1.5 compared to the rms value of the a-c alone of 1.0, the 1.25 factor being the results of averaging three phases.(7) The ratio of peak value to the total rms (1.68 for low-voltage circuits) was used in plotting the current-limiting curves in FIG. 7, in which the curve for each ampere rating becomes tangent to the

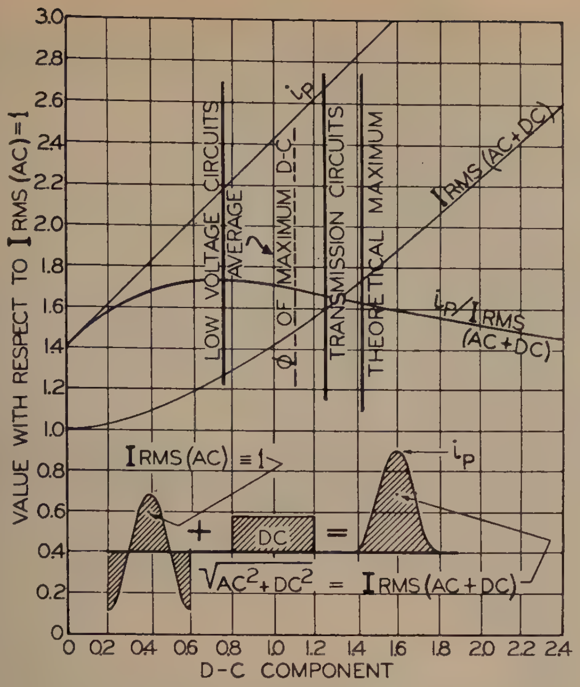

Fig. 10. Numerical relations between peak and rms values of a-c short circuit currents having both a-c and d-c components

line starting at 1680 peak amp for the 1000-rms amp short circuit, and increasing linearly with the available current. The currents at which the current-limiting curves depart from this line are those at which the current-limiting effect commences.

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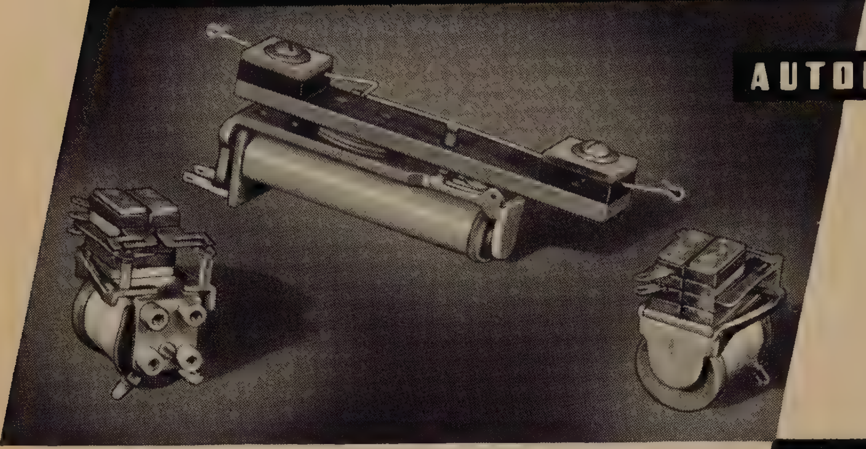

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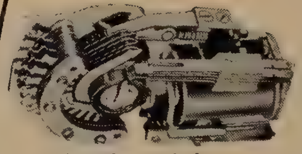

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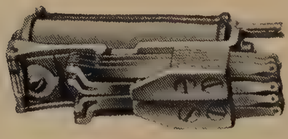

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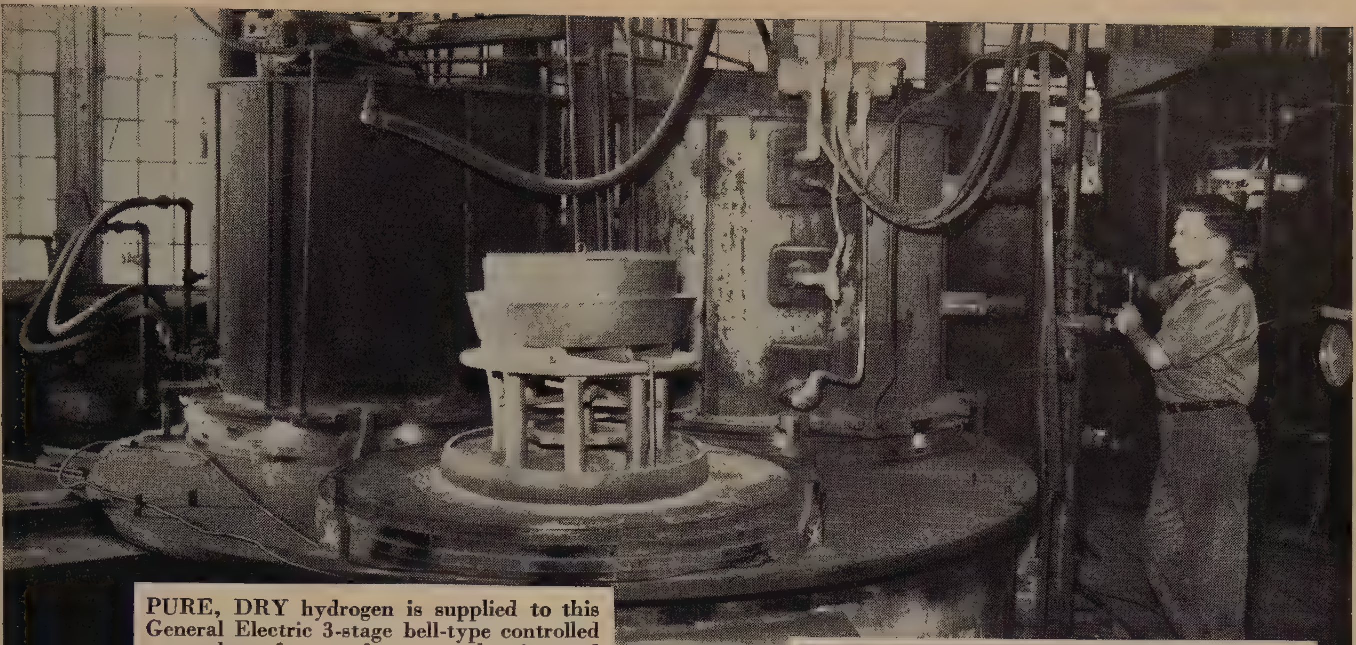

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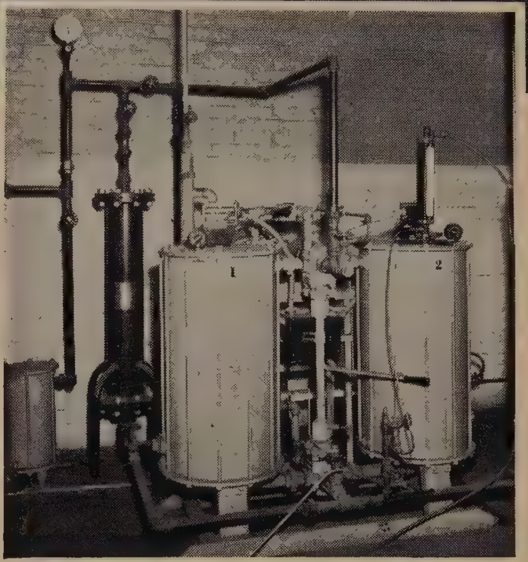

Lectrofilter removes oil vapor. Lectrodryer removes moisture to about -100° F. dewpoint.

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The hydrogen system shown above first removes all oil, then converts any oxygen into water, and finally removes all moisture to dewpoints of about -100° F.

Where your brazing, carburizing, sintering or heat-treating involves controlled atmospheres, consult your gas generator builder. He's an expert. Where a DRY gas is indicated, he'll probably recommend a Lectrodryer.

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VOLTAGE NAMES OF EQUIPMENT AND SYSTEMS

The rise over the years of many different voltage names has brought about need for standard terminology for designating rated voltages of equipment and nominal voltages of systems

By J. R. ELIASON
Industrial Engineering Divisions, Apparatus Department
General Electric Company

ONE of the most important characteristics by which we designate electric equipment and systems is the voltage. So, a reference to voltage is always included in the identification of a piece of electric apparatus or an electric power system.

In speaking of equipment, the voltage to which the operating characteristics are referred is the rated voltage. In speaking of systems, however, rated voltage is not an applicable term, because various pieces of equipment in a given system often have different voltage ratings. Therefore the term "nominal voltage" is used for convenient designation of systems and circuits to define the voltage class.

The problem of proper identification would be easier if all apparatus of a given voltage class had the same voltage rating. Then, of course, the nominal system voltage could have that same value. Undoubtedly, if the industry were starting over again, voltage identification would be made that simple. But, as systems grew, voltages were inched up to compensate for the voltage drop between source and load. Transformers, lamps, motors, and systems were all once on a base of 110 volts; then voltages were raised so that 115 volts was the standard for transformers, lamps, and systems, while motor ratings remained at 110 volts. Consequently there were then two kinds of voltage names: one based on 110 volts for motors, and one based on 115 volts for other equipment. System voltages were raised again sometime after the 208Y/120-volt network was introduced, in order to get voltages as high as feasible for polyphase motors operated from the 208-volt networks. That brought voltage designation up to the 120-volt level for systems and for most power-system equipment except motors and their control.

There are many factors in the over-all picture, but the combined effect has brought us to the point of having different voltage names for the various pieces of equipment and for the systems in a given voltage class. Because of this difference the proper voltage name should always be used in referring to a specific piece of apparatus or to a system. Without an attempt at further explanation of why the present identification system exists, the proper method of designation will be outlined here.

The one-line diagram (FIG. 1) shows a typical method of distributing power in industrial plants, and will be used as reference to identify some portions of the systems and equipment referred to in this article.

RATED VOLTAGES OF TRANSFORMERS

Transformer voltage ratings are based on the no-load values, so that the ratio of primary to secondary rated voltages is equal to the turn ratio.

The transformers have a voltage rating for each winding. These are the voltages at which characteristics are measured; they also represent the turn ratio of the windings, and therefore represent the voltages which will appear at the various terminals at no-load when one winding is excited with rated voltage. The voltage ratio under load depends upon the magnitude and power factor of the load. It is significant that the secondary voltage—for example, 480 volts—is the no-load voltage that will be obtained when rated primary voltage is impressed upon the primary winding. This is normally above the rated voltage of utilization equipment. However, the secondary voltage normally decreases as load is applied to the transformer. Therefore, under load conditions the secondary voltage at the transformer is more nearly equal to the utilization-apparatus voltage ratings. This is why transformer secondary voltage ratings are always higher than motor voltage ratings. What, then, are standard transformer voltage ratings for industrial plants?

Let us first look at primary or master unit substations and transformers which step down from some voltage above 15 kv to plant primary distribution voltage, which is generally below 15 kv (see FIG. 1, top substation). The standard primary winding (*A*, FIG. 1) voltage ratings of this class of substations and transformers are: 110, 67, 43.8, 34.4, and 22.9 kv.

These are the actual transformer winding ratings, derived from the old rating structure based on secondary ratings in multiples of 115 volts. When secondary ratings were boosted to multiples of 120 volts, the high-side rating was raised to maintain the same turn ratio. For instance, 33,000—2300 volts was once a standard rating; the corresponding present-day transformer would be rated 34,400—2400. The familiar designations 115, 69, 46, 34.5, and 23 kv refer to the classes of insulation used with these transformers.

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

Secondary winding (*B*, Fig. 1) voltage ratings of this class of substations and transformers are: 13.8, 13.2, 12, 6.9, 4.8, 4.16, and 2.4 kv.

Next let us look at transformers in load-center unit substations (see Fig. 1, bottom substation) used in the industrial plants for stepping down from plant primary distribution voltage to utilization voltage. As already stated, the plant primary voltage is usually less than 15 kv; therefore the following listing of the primary winding (*C*, Fig. 1) voltage ratings of load-center unit substations includes only voltages below this value. These are: 13.8, 13.2, 12, 6.9, 4.8, 4.16, and 2.4 kv.

Note that the primary voltage rating of this class of transformer (bottom, Fig. 1) is the same as the secondary voltage rating of the primary substation transformers (top, Fig. 1). At one time the primary substation transformers (top, Fig. 1) had a secondary voltage rating one step above the primary voltage rating of the secondary substation transformers (bottom, Fig. 1). For example, the transformer ratio of the primary substation might have been 34.4 to 2.4 kv for supplying primary plant distribution voltage. The secondary substation transformers in the plant would, under the old schedule, have been rated 2.3 kv to 480 volts. By the judicious use of transformer winding taps and use of the load-center system to reduce voltage drop to a minimum, the need for this difference in ratings has disappeared. This has simplified the voltage-rating picture. Under present practice the primary substation (top, Fig. 1) would have a rating of 34.4 to 2.4 kv and the secondary substation (bottom, Fig. 1) in the plant would have a rating of 2.4 to 480 volts.

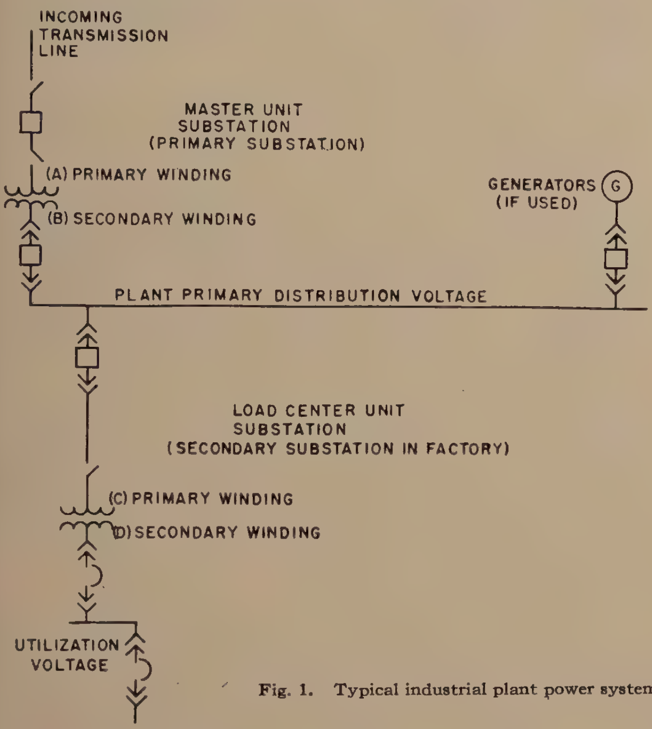
INCOMING TRANSMISSION LINE
MASTER UNIT SUBSTATION (PRIMARY SUBSTATION)
(A) PRIMARY WINDING
(B) SECONDARY WINDING
GENERATORS (IF USED)
G
PLANT PRIMARY DISTRIBUTION VOLTAGE
LOAD CENTER UNIT SUBSTATION (SECONDARY SUBSTATION IN FACTORY)
(C) PRIMARY WINDING
(D) SECONDARY WINDING
UTILIZATION VOLTAGE

Fig. 1. Typical industrial plant power system

The voltage ratings of secondary substations in the plant which supply motors and other utilization equipment are divided into two classes—those for serving utilization equipment above 600 volts, and those for serving utilization equipment below 600 volts. Standard ratings are listed in Table I.

TABLE I

TRANSFORMER SECONDARY (*D* in Fig. 1) VOLTAGE RATINGS FOR SUPPLYING UTILIZATION EQUIPMENT

For Ratings Above 600 Volts	For Ratings 600 Volts or Below
6.9 kv	600 volts (wye or delta)
4.8 kv	480 volts (wye or delta)
4.16 kv	240 volts
2.4 kv	208Y/120 volts

All unit-substation transformers have taps in the primary winding to allow compensation for voltages that vary from the transformer rating. The most common method of tap changing is manual operation with the transformer de-energized. There are four taps—two 2½ percent above and two 2½ percent below normal—giving a total adjustment of plus or minus 5 percent. Automatic tap changing under load, or load ratio control, is available in package or master unit substations with a range of plus or minus 10 percent.

Combined light and power systems are frequently used where motors are supplied at 480 volts, for example; and lights are supplied at 120 volts from the same 480-volt system, using dry-type transformers. The standard primary voltage ratings for these lighting transformers are: 600 volts, 480 volts, and 240 volts; and the standard secondary voltage ratings are: 208Y/120 volts and 120/240 volts. Two 5-percent taps below normal are provided in these transformers to allow for operation of 120-volt lamps near their rated voltage when the voltage on the 480-volt system is below 480 volts, as it normally will be.

Transformer voltage designations become rather complex. For instance, windings may have series-parallel connections. Or they may be designed for connection line-to-neutral on higher-rated-voltage systems, such as 2400-volt transformers which are suitable for line-to-neutral operation on 4160-volt systems. These and other complex arrangements make exact identification desirable. This is covered in more detail in the appendix at the end of the article.

RATED VOLTAGES OF GENERATORS

Since the generator is a source of electric power and is often in parallel with primary substation transformers (see Fig. 1), its voltage, and consequently its rating, is in practically all cases the same as the transformer's in a given voltage class. Listed here are the three-phase generator ratings that are recommended by the latest EEI-NEMA report:

120 volts
208Y/120 volts
240 volts
480 volts
600 volts
2400 volts
4160 volts
4800 volts
6900 volts
*11,500 volts
*12,500 volts
13,800 volts
14,400 volts

---

*These ratings differ from transformer ratings. The corresponding transformer rating is 12,000 volts. Transformer taps allow for operating in parallel with generators of either of these voltage ratings.

The 14,400-volt rating has been adopted largely in large generating stations where the input is transformed up to higher voltage in a unit transformer-generator scheme (see FIG. 2).

MOTOR RATED VOLTAGES

At the other end of the system are the motors; and their ratings reflect the fact that, because of voltage drop, voltage at utilization equipment is somewhat lower than at the sources of power.

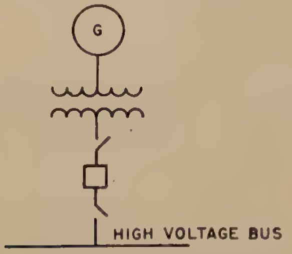

Fig. 2. Unit transformer-generator scheme

In Table II it will be evident that the motor voltage ratings are less than transformer ratings or nominal system voltage. For example, 6.6-kv motors would be used on systems whose nominal rating is 6.9 kv and which are supplied by transformers whose secondary ratings are 6.9 kv; 440-volt motors would be used on systems whose nominal ratings are 480 volts and which are supplied by transformers whose secondary ratings are 480 volts.

Single-phase motors are usually rated 115 or 230 volts. The standard voltage ratings of polyphase motors are:

110 volts
208 volts
220 volts
440 volts
550 volts
2300 volts
4000 volts
4600 volts
6600 volts
11,000 volts
13,200 volts

The spread between source-equipment rating and motor rating is not so great in the higher voltage classes, because voltage drops are not so pronounced. For instance, motors supplied by 2400-volt sources used to be rated at 2200 volts; however, they are now rated at 2300 volts to bring the rating more nearly in line with the voltages actually encountered in service.

RATED VOLTAGES OF LAMPS

Incandescent lamps are standardized at 120 volts. Higher voltages have not, in general, been found satisfactory.

Fluorescent lamps offer a wider range of operation and are commonly rated 118, 208, 236, and 265 volts (for line-to-neutral on 480-volt systems). If fluorescent lamps become available for operation across the lines of 480-volt systems, then their rating will probably be 460 volts.

TABLE II

BASIC PATTERN OF VOLTAGE IDENTIFICATION

Nominal System Voltage	Generator Rated Voltage	Transformer Secondary Rated Voltage	Transformer Primary Rated Voltage	Motor Rated Voltage **	Lamp Rated Voltage
		Single-phase Systems			
120 or 120/240	120 or 120/240	120 or 120/240	120	115	118 or 120
240 or 120/240	240 or 120/240	240 or 120/240	240	230	236
208Y/120	208Y/120	208Y/120	120	115	118 or 120
		Three-phase Systems			
120	120	120	120	110	118 or 120
*208Y/120	208Y/120	208Y/120	208 or 120	208 or 110	208 or 118 or 120
240	240	240	240	220	236
*480	480	480	480	440	265
600	600	600	600	550	
*2400	2400	2400	2400	2300	
*4160	4160	4160	4160	4000	
4800	4800	4800	4800	4600	
*6900	6900	6900	6900	6600	
11,500	11,500	12,000	12,000	11,000	
12,000	12,500	12,000	12,000	11,000	
13,200	13,800	13,200	13,200	13,200	
*13,800	13,800	13,800	13,800	13,200	
22,900			22,900		
34,400			34,400		
43,800			43,800		
67,000			67,000		
110,000			110,000		

*In new installations, or wherever a selection of voltage can be made, these are the preferred system voltages.
**Specifying these values for motor voltages is important: For instance, motors to operate on 4160, 6900, or 13,800-volt systems should be rated 4000, 6600, or 13,200 volts respectively.

OTHER APPARATUS

Some other types of equipment, such as capacitors and industrial heating equipment, have compromised between the extremes of generator rating and motor rating in a given voltage class. Industrial heating devices are rated 115, 230, 460, and 575 volts. Capacitors are rated 230, 460, 575, 2400, 4800, 7200, 12,470, and 13,800 volts.

Motor control equipment has the same voltage rating as the associated motor.

NOMINAL SYSTEM VOLTAGES

The choice of the numerical value to represent nominal system voltage is purely arbitrary and does not attempt to indicate an average system voltage. It is merely a name. However, it is highly desirable that a consistent practice in designating nominal voltages be followed. When used properly, the nominal voltage should give a good picture of the voltage structure of a system, with a minimum of misunderstandings. The standard values for nominal system voltage correspond to the ratings of source equipment. Table III is not complete but is representative of industrial practice.

TABLE III

STANDARD NOMINAL SYSTEM VOLTAGES

	Single-phase	
	120	
	120/240	
	240	
	Three-phase	
120	4160	13,800
208Y/120	4800	22,900
240	6900	34,400
480	11,500	43,800
600	12,000	67,000
2400	13,200	110,000

SUMMARY

The voltage identification structure is summarized in Table II. For each of the nominal system voltages listed, the table gives voltage ratings of generators, transformers, motors, and (in some cases) lamps. To illustrate the use of Table II, consider a 13,800-volt system. The generators would be rated 13,800 volts. Transformers stepping power down from transmission voltage would have secondary windings (*B*, Fig. 1) rated 13,800 volts. Transformers stepping power down to utilization voltage in load-center substations would have primary windings (*C*, Fig. 1) rated 13,800 volts. Motors connected directly to the 13,800-volt bus would be rated 13,200 volts.

In describing electric equipment, it is not enough to say merely "equipment for a 13,800-volt system." Each piece of equipment should get individual attention from the standpoint of voltage rating.

APPENDIX: TRANSFORMER VOLTAGE REPRESENTATIONS

Transformer voltage ratings have long been expressed by various symbolic methods. Such methods are essential, because to fully describe the windings of transformers would often require a fairly lengthy paragraph. However, to be of any value, a transformer rating so expressed should mean the same to everyone. To further a consistent use of symbols, both NEMA and ASA Standards have been established to recommend a standard transformer "shorthand."

Four symbols are used: ~~the~~ dash (—), the slant (/), the X, and the Y. In general terms, their uses are as follows:

Dash (—). Used to separate the voltage ratings of separate windings in a specific transformer.

Slant (/). Used to separate voltages to be applied to or obtained from the same winding.

X. Used to designate separate voltages obtainable by reconnection of the coils of a winding in series or multiple combinations.

Y. Used to designate a winding that is wye-connected. The absence of this symbol in a three-phase transformer rating indicates that the winding is delta-connected.

The use of the dash, slant, and wye can be easily illustrated by the voltage rating of the transformer for a typical load-center substation.

4160—480Y/277: This means the 4160-volt high-voltage winding is delta-connected, while the 480-volt winding is wye-connected with the neutral brought out. A three-winding transformer might have this voltage rating: 13,800—2400—480Y/277.

In three-phase transformers, the slant is often used to indicate windings connectable in either delta or wye. For example, a 2400/4160Y winding can be connected either for 2400 volts delta, or for 4160 volts wye. Note that the delta voltage is expressed first. When a wye-connected winding has the neutral brought out it is signified thus: 208Y/120. Here the line voltage is expressed first, followed by the line-to-neutral voltage. If the neutral is brought out with reduced insulation, that fact is shown by 208 Grd Y/120.

Another use of the slant is to indicate taps, especially on single-phase transformers. A 240-volt winding with a mid-tap is expressed 240/120. When a single-phase transformer with a series-multiple winding is wound to be suitable for three-wire service on the series connection, it is designated 120/240. When a winding has several taps close to the rated voltage, it is customary to specify them as illustrated in this specific case: Four 2½ percent rated kva taps, two above and two below rated voltage.

The symbol X is used to separate the voltages obtainable in a series-multiple winding not suitable for three-wire operation. For example, a winding rated 120 x 240 can be connected with the coils in parallel to obtain 120 volts, or with the coils in series for 240 volts.

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GENERAL ELECTRIC

856-54

PRACTICAL ENGINEERING USES OF PROBABILITY PAPER

Part II

Probability paper and tables deal with continuous variables; algebra deals with stepped variables. A bridge between the two systems makes possible intellegent application of the convenient probability paper to the algebraic type of problem. Tables are more accurate, and sometimes more convenient, than probability paper, but the paper gives a picture of the degree to which the data fit the normal law

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THE METHOD of algebra in probability is very different from that of the normal-law paper or table because algebra deals with stepped—that is, discontinuous—variables, the normal law with continuous ones. A bridge between the two methods is very desirable, because the normal-law is incomparably easier to use. Such a bridge exists.

What we need for this purpose is a method of calculating y_m and σ for the algebraic type of problem, and fortunately the method is contained in two simple formulas, given here as Equations (5) and (6).

If the probability of success in one trial is p, and s trials are to be made, then

$$y_m = sp \tag{5}$$

$$\text{and} \quad \sigma = \left\{ sp\,(1\text{-}p) \right\}^{½} \quad \sigma \text{ in absolute value} \tag{6a}$$

$$= \left\{ p\,(1\text{-}p)/s \right\}^{½} \quad \sigma \text{ in per unit value} \tag{6b}$$

For example, a coin is tossed 100 times. What is the probability of getting 60 heads or more? As $s=100$, and $p=0.5$, then $y_m=50$, $\sigma=5$, and the graph is a straight line as shown in FIG. 11. In terms of a continuous variable, our problem is to calculate the probability of 59.5 heads or more per hundred throws, because any tendency for a fractional number of heads will show up as the nearest integer. From the graph, the desired probability is $100-97.1=2.9$ percent. The probability of *either heads or tails* being 60 or over is then $2\times2.9=5.8$ percent. The algebraic solution(6) of this problem is rather laborious and will not be given here, but the answer is given by Brownlee as 5.69 percent.(4)

Before leaving this example, let us answer another question about this case. At least how many heads or tails per hundred throws will cast doubt on the coin or tosser being unbiased? In industrial quality control, an observation as high as $\pm3\sigma$ or more (representing 0.27 percent probability) is considered good and sufficient reason to start an investigation. On the basis of that criterion, then, 65 heads (or tails) would justify suspicion of bias.

In industrial problems, ordinarily we do not know the probability of "success in one trial" p, but generally do have or can have samples to obtain an estimated value.

One limitation of applying a continuous probability curve to an integral-valued variable is that, as the curve extends to infinity on either side, it runs into impossible values of y. Thus, in FIG. 11, the curve would give finite probability values for more than 100 heads (per 100 throws), and also for less than zero (negative number of) heads! Properly interpreted, this does no harm. To illustrate the "proper" interpretation—as any number of heads from 99.5 to plus infinity has to show up as 100 heads, and any number of heads 0.5 or less (down to minus infinity) as 0 heads—therefore, the probability of 100 heads out of a hundred throws (or zero heads out of a hundred throws) as reckoned by algebra will correspond, in the continuous curve (FIG. 11), to the probability of half a head or less. This is a deviation from the mean value ($y_m=50$) of $(49.5/5)\sigma$ or 9.9σ. Neither our graph nor the probability tables go that far, but from algebra the answer is 0.5^{100}, equal to 0.8×10^{-30}, an infinitesimal probability. We should not expect good agreement between the two methods at such an extreme range of probability. What degree of agreement may be expected between the two methods at the upper and the lower ends of these graphs is illus-

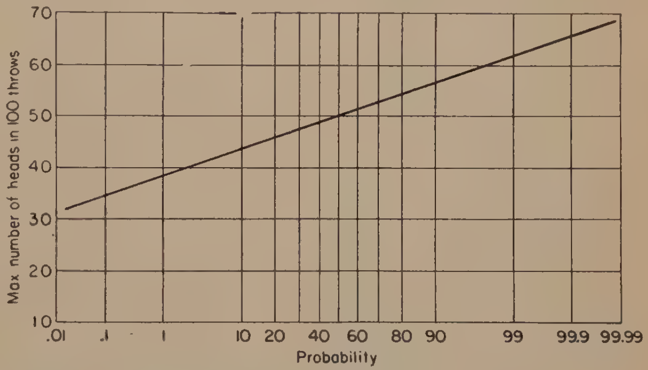

Fig. 11. Is the coin loaded? A graphical solution is simpler than the algebraic, but within limits of applicability

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(4) *Industrial Experimentation* p. 36–37, cited in Part I.

(6) The algebraic formula for the probability, P_k, of k successes in s throws, when the probability of success in one throw is p, is

$$P_k = C_k^s\, p^k\,(1-p)^{s-k}$$

in which C_k^s is the combination of s things k at a time.

P_k is also the term containing p^k in the expansion of $(p+q)^s$ in which q stands for $(1-p)$. This method was used for the calculation of the curves in FIGS. 12 and 13.

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

TABLE VIII

PROBABILITY INTEGRALS

$$P=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{x/\sigma}\epsilon^{\,-\frac{(x/\sigma)^2}{2}}\,d(x/\sigma)$$

This table of probability integrals differs from conventional tables, having been arranged on a basis most convenient for engineering applications. It is on the same basis as the abcissae of the probability paper. Its meanings and uses are as follows:-

x = Absolute algebraic value of the deviation of an individual case from the mean value of all cases.

σ = Root-mean-square deviation of all the cases from their mean value.

The entries in the table give the probability that the deviation of a single case at random from the mean value will be algebraically less than the corresponding x/σ.

EXAMPLE. A product has a standard deviation of 12:

(1) What is the probability that a random unit will not deviate by more than (+9) from the mean? Ans.: x/σ = 9/12 = 0.75. Hence, from the table, the probability is 0.773, or 77.3%.

(2) What is the probability that the deviation of the random unit will exceed (+18)? Ans.: x/σ = 18/12 = 1.5. From the table, the probability is 1 - 0.93319 = .06681, or 6.68%.

(3) What is the probability that the deviation of the random sample will fall between (+9) and (+18)? Ans.: $p_{18/12} - p_{9/12} = 0.93319 - 0.77337 = 0.1598$, or 15.98%.

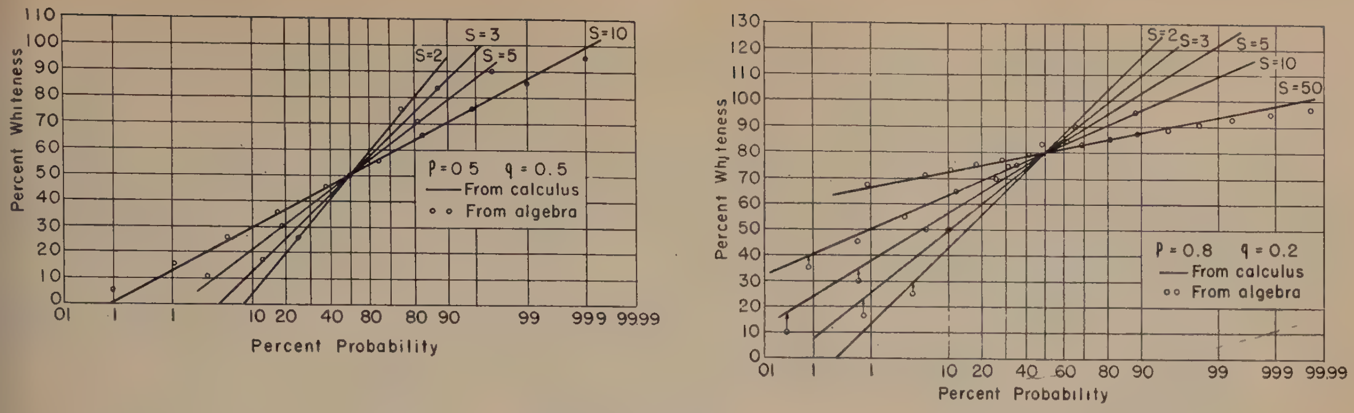
(4) What is the probability that the deviation will be worse than (-24)? Ans.: x/σ = -24/12 = -2. Hence, from the table, 0.02275, or 2.27%.

(5) What is the probability that the true mean value differs by not more than (±3), assuming that 210 cases have been averaged. Ans.: $3\sqrt{210}/12 = 3.62$. Hence, from the table, $p_{+3.62} - p_{-3.62} = 0.99985 - 0.00015 = 0.99970$, or 99.97%.

(6) If an actual deviation, with less than 1/10,000 probability, may be looked upon with suspicion, what is the limit of passable deviation? Ans.: Looking up the x/σ corresponding to a probability of 0.00010, x/σ = ±3.72.

(7) What is the probability of a deviation worse than $\pm 3\sigma$? Ans.: $1 - (p_{+3} - p_{-3}) = 1 - (0.99865 - 0.00135) = 0.0027$, or 0.27%.

x/σ	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
-∞	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
-3.9	.00005	.00005	.00004	.00004	.00004	.00004	.00004	.00004	.00003	.00003
-3.8	.00007	.00007	.00007	.00006	.00006	.00006	.00006	.00005	.00005	.00005
-3.7	.00011	.00010	.00010	.00010	.00009	.00009	.00008	.00008	.00008	.00008
-3.6	.00016	.00015	.00015	.00014	.00014	.00013	.00013	.00012	.00012	.00011
-3.5	.00023	.00022	.00022	.00021	.00020	.00019	.00019	.00018	.00017	.00017
-3.4	.00034	.00032	.00031	.00030	.00029	.00028	.00027	.00026	.00025	.00024
-3.3	.00048	.00047	.00045	.00043	.00042	.00040	.00039	.00038	.00036	.00035
-3.2	.00069	.00066	.00064	.00062	.00060	.00058	.00056	.00054	.00052	.00050
-3.1	.00097	.00094	.00090	.00087	.00084	.00082	.00079	.00076	.00074	.00071
-3.0	.00135	.00131	.00126	.00122	.00118	.00114	.00111	.00107	.00103	.00100
-2.9	.00187	.00181	.00175	.00169	.00164	.00159	.00154	.00149	.00144	.00139
-2.8	.00256	.00248	.00240	.00233	.00226	.00219	.00212	.00205	.00199	.00193
-2.7	.00347	.00336	.00326	.00317	.00307	.00298	.00289	.00280	.00272	.00264
-2.6	.00466	.00453	.00440	.00427	.00415	.00402	.00391	.00379	.00368	.00357
-2.5	.00621	.00604	.00587	.00570	.00554	.00539	.00523	.00508	.00494	.00480
-2.4	.00820	.00798	.00776	.00755	.00734	.00714	.00695	.00676	.00657	.00639
-2.3	.01072	.01044	.01017	.00990	.00964	.00939	.00914	.00889	.00866	.00842
-2.2	.01390	.01355	.01321	.01287	.01255	.01222	.01191	.01160	.01130	.01101
-2.1	.01786	.01743	.01700	.01659	.01618	.01578	.01539	.01500	.01463	.01426
-2.0	.02275	.02222	.02169	.02118	.02068	.02018	.01970	.01923	.01876	.01831
-1.9	.02872	.02807	.02743	.02680	.02619	.02559	.02500	.02442	.02385	.02330
-1.8	.03593	.03515	.03438	.03362	.03288	.03216	.03144	.03074	.03005	.02938
-1.7	.04457	.04363	.04272	.04182	.04093	.04006	.03920	.03836	.03754	.03673
-1.6	.05480	.05370	.05262	.05155	.05050	.04947	.04846	.04746	.04648	.04551
-1.5	.06681	.06552	.06426	.06301	.06178	.06057	.05938	.05821	.05705	.05592
-1.4	.08076	.07927	.07780	.07636	.07493	.07353	.07214	.07078	.06944	.06811
-1.3	.09680	.09510	.09342	.09176	.09012	.08851	.08691	.08534	.08379	.08226
-1.2	.11507	.11314	.11123	.10935	.10749	.10565	.10383	.10204	.10027	.09853
-1.1	.13567	.13350	.13136	.12924	.12714	.12507	.12302	.12100	.11900	.11702
-1.0	.15866	.15625	.15386	.15150	.14917	.14686	.14457	.14231	.14007	.13786
-0.9	.18406	.18141	.17879	.17619	.17361	.17106	.16853	.16602	.16354	.16109
-0.8	.21186	.20897	.20611	.20327	.20045	.19766	.19489	.19215	.18943	.18673
-0.7	.24196	.23885	.23576	.23270	.22965	.22663	.22363	.22065	.21770	.21476
-0.6	.27425	.27093	.26763	.26435	.26109	.25785	.25463	.25143	.24825	.24510
-0.5	.30854	.30503	.30153	.29806	.29460	.29116	.28774	.28434	.28096	.27760
-0.4	.34458	.34090	.33724	.33360	.32997	.32636	.32276	.31918	.31561	.31207
-0.3	.38209	.37828	.37448	.37070	.36693	.36317	.35942	.35569	.35197	.34827
-0.2	.42074	.41683	.41294	.40905	.40517	.40129	.39743	.39358	.38974	.38591
-0.1	.46017	.45620	.45224	.44828	.44433	.44038	.43644	.43251	.42858	.42465
-0.0	.50000	.49601	.49202	.48803	.48405	.48006	.47608	.47210	.46812	.46414
+0.0	.50000	.50399	.50798	.51197	.51595	.51994	.52392	.52790	.53188	.53586
+0.1	.53983	.54380	.54776	.55172	.55567	.55962	.56356	.56749	.57142	.57535
+0.2	.57926	.58317	.58706	.59095	.59483	.59871	.60257	.60642	.61026	.61409
+0.3	.61791	.62172	.62552	.62930	.63307	.63683	.64058	.64431	.64803	.65173
+0.4	.65542	.65910	.66276	.66640	.67003	.67364	.67724	.68082	.68439	.68793
+0.5	.69146	.69497	.69847	.70194	.70540	.70884	.71226	.71566	.71904	.72240
+0.6	.72575	.72907	.73237	.73565	.73891	.74215	.74537	.74857	.75175	.75490
+0.7	.75804	.76115	.76424	.76730	.77035	.77337	.77637	.77935	.78230	.78524
+0.8	.78814	.79103	.79389	.79673	.79955	.80234	.80511	.80785	.81057	.81327
+0.9	.81594	.81859	.82121	.82381	.82639	.82894	.83147	.83398	.83646	.83891
+1.0	.84134	.84375	.84614	.84850	.85083	.85314	.85543	.85769	.85993	.86214
+1.1	.86433	.86650	.86864	.87076	.87286	.87493	.87698	.87900	.88100	.88298
+1.2	.88493	.88686	.88877	.89065	.89251	.89435	.89617	.89796	.89973	.90147
+1.3	.90320	.90490	.90658	.90824	.90988	.91149	.91309	.91466	.91621	.91774
+1.4	.91924	.92073	.92220	.92364	.92507	.92647	.92786	.92922	.93056	.93189
+1.5	.93319	.93448	.93574	.93699	.93822	.93943	.94062	.94179	.94295	.94408
+1.6	.94520	.94630	.94738	.94845	.94950	.95053	.95154	.95254	.95352	.95449
+1.7	.95543	.95637	.95728	.95818	.95907	.95994	.96080	.96164	.96246	.96327
+1.8	.96407	.96485	.96562	.96638	.96712	.96784	.96856	.96926	.96995	.97062
+1.9	.97128	.97193	.97257	.97320	.97381	.97441	.97500	.97558	.97615	.97670
+2.0	.97725	.97778	.97831	.97882	.97932	.97982	.98030	.98077	.98124	.98169
+2.1	.98214	.98257	.98300	.98341	.98382	.98422	.98461	.98500	.98537	.98574
+2.2	.98610	.98645	.98679	.98713	.98745	.98778	.98809	.98840	.98870	.98899
+2.3	.98928	.98956	.98983	.99010	.99036	.99061	.99086	.99111	.99134	.99158
+2.4	.99180	.99202	.99224	.99245	.99266	.99286	.99305	.99324	.99343	.99361
+2.5	.99379	.99396	.99413	.99430	.99446	.99461	.99477	.99492	.99506	.99520
+2.6	.99534	.99547	.99560	.99573	.99585	.99598	.99609	.99621	.99632	.99643
+2.7	.99653	.99664	.99674	.99683	.99693	.99702	.99711	.99720	.99728	.99736
+2.8	.99744	.99752	.99760	.99767	.99774	.99781	.99788	.99795	.99801	.99807
+2.9	.99813	.99819	.99825	.99831	.99836	.99841	.99846	.99851	.99856	.99861
+3.0	.99865	.99869	.99874	.99878	.99882	.99886	.99889	.99893	.99897	.99900
+3.1	.99903	.99906	.99910	.99913	.99916	.99918	.99921	.99924	.99926	.99929
+3.2	.99931	.99934	.99936	.99938	.99940	.99942	.99944	.99946	.99948	.99950
+3.3	.99952	.99953	.99955	.99957	.99958	.99960	.99961	.99962	.99964	.99965
+3.4	.99966	.99968	.99969	.99970	.99971	.99972	.99973	.99974	.99975	.99976
+3.5	.99977	.99978	.99978	.99979	.99980	.99981	.99981	.99982	.99983	.99983
+3.6	.99984	.99985	.99985	.99986	.99986	.99987	.99987	.99988	.99988	.99989
+3.7	.99989	.99990	.99990	.99990	.99991	.99991	.99992	.99992	.99992	.99992
+3.8	.99993	.99993	.99993	.99994	.99994	.99994	.99994	.99995	.99995	.99995
+3.9	.99995	.99995	.99996	.99996	.99996	.99996	.99996	.99996	.99997	.99997
+∞	1.00000									



Figs. 12 and 13. Expected degree of agreement between algebraic and graphical methods. In Fig. 12, $p=0.5$; in Fig. 13, $p=0.8$

trated in FIG. 12 for $p=0.5$, and in FIG. 13 for $p=0.80$. The lines are based on y_m and σ, and the circles are calculated by algebra.(6) Based on these figures, the useful range of these curves with engineering accuracy might be said to be between the 1 percent probability point and the 99 percent probability point.

PROBABILITY TABLE VS PAPER

A little probability table like Table VIII will do all that this special paper will do, and do it also more accurately, but it will be far less convenient than the paper in seeing how well the data are consistent with the normal law. The graph shows this at a glance to the satisfaction of any engineer used to plotting data. Besides, if Table VIII is to be used instead of the paper, a laborious correlation calculation has to be made. Assuming that we undertake this labor and find a 69 percent correlation, what shall we say that means? Whatever it means, it cannot be as eloquent to the engineer as seeing the arrangement of the individual data around the straight line.

Table VIII is arranged to give the probability of an individual case having a value less than $y_m+k\sigma$ for various positive and negative values of k ($={}^x/_\sigma$ in the tabulation). It is instructive to verify from that table the following results, which are well worth committing to memory:

Range	*Probability*
$y_m \pm 0.67\sigma$	50%
$y_m \pm \sigma$	68%
$y_m \pm 2\sigma$	95%
$y_m \pm 3\sigma$	99.7%

CONCLUSIONS

(1). Like the sine wave, the normal probability law is an ideal, not fulfilled exactly by any practical problem, but it is frequently approximated well enough to justify its general use in the absence of evidence to the contrary. The probability paper serves this purpose very nicely by reducing the graphs to straight lines based on mean value and standard deviation.

(2). The permissibility of the use of the normal law in a given case may be verified within engineering standards by plotting the available data individually on probability paper and seeing if they are consistent with the straight line based on the mean value and standard deviation of the data.

(3). The normal law assumes that the variable can have values above and below the mean value without limit, which, therefore, implies also negative values for the variable. When it is known that a variable cannot be less than a certain figure (for instance, 0) or more than a certain figure (for instance, 100 percent), the graph may not be reliable outside the range of 1–99 percent probability or in the neighborhood of those limiting points.

(4). Probability paper (or table) may be used very conveniently, though approximately, for "stepped" variables dealt with in algebra. The approximation is better the greater the ratio of the value of the variable to the width of the minimum possible step in it, approximating a continuous variable. This leads to the fortunate situation that, the less applicable the paper is, the more easily is the problem solvable by algebra; and the more difficult the algebraic solution is, the greater is the accuracy of the probability-paper (or table) solution.

(5). Quality control by probability charts is based on the theory that the occurrence of an event of very low probability justifies investigation into an assignable cause for its occurrence. For this purpose, it has become customary to set the warning lines for "very low probability" at ±3σ.

(Concluded)

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Mallory is a leading producer of unusual alloys and materials from such non-ferrous metals as copper, silver, platinum, palladium, tungsten, molybdenum. In addition to these unusual alloys, the company specializes in pure copper, aluminum-bronze, nickel and nickel alloys. The well equipped laboratories at Mallory are staffed by competent and highly trained metallurgists, chemists, and electrical and mechanical engineers. This places Mallory in a qualified position to make effective and impartial recommendations for materials best suited to our customers' needs.

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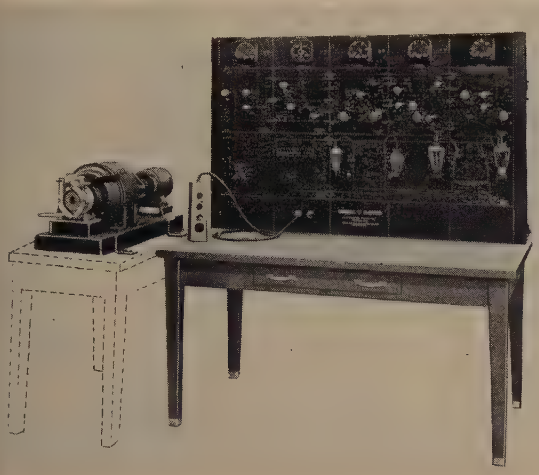
HIGH LIGHTS and SIDE LIGHTS

Educational Thy-Mo-Trol Drive

A new full-wave reversing educational Thy-mo-trol drive has been designed to assist in the teaching of electronic motor control and associated circuits.

The demonstration equipment consists of seven circuit panels and five instrument panels assembled on a steel frame, mounted vertically on a steel table. The circuit diagrams are molded in white into the front of the dark panels. The actual wiring and all components except the tubes are behind the panels, with all important circuit points brought to the front of the panel by insulated banana-plug jacks.



Educational Thy-mo-trol drive includes table and motor, tachometer, and manual brake assembly

The Thy-mo-trol motor, tachometer generator, and manually operated brake are mounted on a common subbase for separate mounting by the school. The control station is mounted on the table, and the anode transformer is also on the table behind the panel. The instrument panels are across the top of the control panel assembly. This location, together with the use of long-scale instruments, makes the equipment particularly suitable for group instruction or demonstration.

The control panel has been especially designed to make circuit study easy for the student. The diametric half-wave circuit used has been laid out in elementary form. Simple triodes rather than multiple tubes have been used throughout in order to make it easier for the student to analyze the various parts of the circuit. The panel operates on a 220-volt single-phase 60-cycle line.

The motor furnished is a special 1-hp d-c Thy-mo-trol motor, with double shaft extension. This, with a tachometer generator mounted at one end and a manually operated, spring-release loading brake at the other, is mounted on a suitable base and can be located as a unit at any convenient place for test or demonstration. The motor can be operated over the range of from 2300 to 1150 rpm by field control and from 1150 to 46 rpm by armature-voltage control.

Reversing is accomplished by means of magnetic switches, which reverse the armature connections. Thus, the d-c motor may be at its maximum rpm rating and be reversed instantly.

The circuits are subdivided on panels so that individual panels can be isolated and used for the study of fundamental portions of industrial electronic circuits. The complete unit includes the anode transformer, control station, motor assembly, and table-mounted panel.

Thy-mo-trol equipment, which has become an important tool in modern industry, provides wide-range stepless speed control of d-c motors operating from an a-c circuit while maintaining essentially constant speed with constant torque output.

Nonferromagnetic Synchrotron

A new type of particle accelerator, which is ultimately expected to produce x rays of 300,000,000 volts, was recently reported successful in operation in its first phase.

Known as a "nonferromagnetic synchrotron," the new machine has been operated thus far up to about a million volts and is expected to be in operation at much higher energies before the end of the year. It will be used to study the effects of high-energy radiation, particularly in nuclear research.

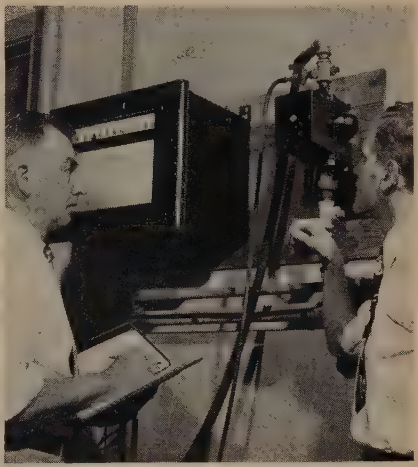
This new particle accelerator is of a design that eliminates the huge iron-core electromagnet commonly used in such devices. The requisite powerful magnetic fields are produced solely by specially designed coils in a cylindrical steel tank 26 in. high and 6½ ft in diameter, with one-inch-thick walls, from which air has been exhausted. By means of this group of coils initial betatron acceleration and subsequent synchrotron operation are obtained.

There is no separate "doughnut", as in the earlier type, since the entire tank is evacuated and the electrons move in the space between the inner and outer coils. During first operation the vacuum was about a hundred millionth of an atmosphere. This allows enough gas molecules to remain to cause appreciable scattering of the electrons, though it does not prevent operation. As the vacuum is improved, to a billionth of an atmosphere or better, the scattering may be decreased accordingly.

Turbidity Recorder

The clearness of liquids, from tap water to muddy Missouri River water, can be measured by a new photoelectric instrument called the "recording turbidimeter," which continuously measures and records the quantity of particles suspended in fluids flowing through it.

The turbidimeter provides a means of checking and controlling processes in water-treatment and sewage-disposal plants, and in other operations where turbidity is an important consideration.



Typical laboratory installation of the turbidimeter

As a light beam is sent through the fluid that is passed through the automatic instrument, three electric eyes measure the percentage of light that travels in a straight path as compared with light scattered to the sides by suspended particles.

The turbidimeter is expected to fulfill the requirements of water turbidity reports required by many state health departments, and will save laboratory technicians' time by making the measure-

(Continued on following page)

HIGH LIGHTS (Continued)

ments automatically. It can also alert operators immediately if turbidity exceeds predetermined limits.

The equipment should be useful in certain chemical processes as well as in sanitation engineering, according to its designers. It is capable of determining the end-points of processes in which salts are precipitated out of solutions, and of monitoring chemical wastes to see whether they should be treated.

Zncube

Zinc, in the past a weak metal of little use in engineering, now can be made as strong as brass. A newly developed alloy composed principally of zinc, with small quantities of copper and beryllium added, is reported to have approximately the same strength and electrical characteristics as brass. The alloy is also said to be considerably cheaper than brass.

Called "zncube" (pronounced zin-cue-be), from the chemical symbols for its makeup, the alloy has about eight times the useful strength of any other zinc alloy now in use. A foot-long strip of ordinary zinc $\frac{1}{16}$ in. thick will droop slowly from its own weight when held horizontal at one end. With the addition of a small percentage of copper and beryllium, however, zinc takes on a springy, resilient quality.

Among applications in which cheaper zncube might be substituted for brass are listed lamp and fuse sockets and bases, panels, containers, mild springs, and many forms of hardware. The alloy is said to machine, solder, and resistance-weld easily.

New Compound Discovered By Mass Spectrometer

Evidence pointing to the existence of a hitherto unknown compound of the elements boron and hydrogen has been found. The discovery was believed to have been the first of its kind made by the mass spectrometer.

A number of compounds of boron and hydrogen, which are called boron hydrides and have many important possible applications, have been studied, particularly in regard to the way they decompose. In these the proportion of boron to hydrogen is 2 to 6, 4 to 10, 5 to 11, 10 to 14, etc. The new compound seems to have the proportion of 9 to 13, which would make its chemical formula B_9H_{13}.

The mass spectrometer, which has been termed an "electronic chemist," is now widely used for rapid chemical analysis.

A small amount of the substance to be studied is admitted, in gaseous form, to an exhausted tube in the instrument, where it is bombarded by a stream of electrons. Ions of different weights are sorted out into a spectrum; a collector plate picks up ions of a certain mass, and their intensity is measured by the current they carry. A record of the current from the collecting plate is recorded as a line with a number of peaks, each peak corresponding to a combination of ions of particular mass.

Some boron atoms have a mass of 10 units, and others of 11, while each hydrogen has one unit of mass. Consequently the hydride containing 10 boron atoms to 14 of hydrogen has a group of peaks around 115 units.

Examination of the mass spectrum of a hydride with the 5-to-11 ratio which had been stored for a considerable time at a temperature of −108 F revealed that it had partially decomposed into several others, including the 10-14 combination, which showed its usual peaks on the chart, also peaks around 105 units, corresponding to no boron hydride now known.

There are two series of the hydrides, one of which is stable and contains four more hydrogen atoms than boron atoms; the other compounds, which are unstable, have six extra hydrogens. Scientists have suggested that the new compound may belong to the stable series, so to make 105 units it would have the nine to 13 proportion. However, it is believed not impossible that it belongs to the unstable series, with the proportion of nine to 15. In this case there would have to be more of the lighter kind of boron atoms to keep the total mass about the same.

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NEW PRODUCTS: AND WHAT THEIR MAKERS HAVE TO SAY ABOUT THEM

Cable-fault Locator

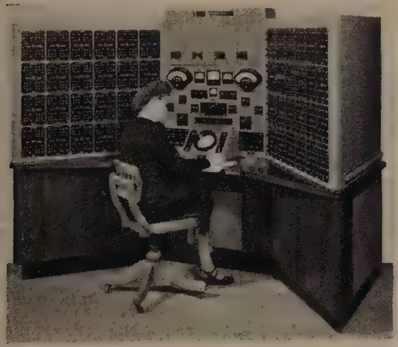
A high-voltage d-c impulse transmitter with pickup coil and pointer indicating detector comprise a new cable-fault locator, Model 2-2, designed primarily for locating faults on lead-covered cable installed in ducts. It can be used also on aerial and buried cable, and is effective in utility and industrial service. In operation the set is essentially independent of the type of fault or its apparent resistance, and depends only on the impulse voltage required to break down the fault. The device is rated up to 20 kv with a discharge capacitance of 2.5 μf, for use on all cable up to 15 kv and higher. The set requires about 500 watts to operate, from a 115-volt source.—*James G. Biddle Co., 1316 Arch St., Philadelphia 7, Pa.*

Rod and Tube

Teflon, technically known as polytetrafluorethylene, is now furnished in rod and tubing form for machining purposes. It has a number of applications in the electrical and electronic fields where it is used as a high-frequency insulation. In many processing industries Teflon is used because of its almost complete inertness, high-temperature resistance, and nonsticking qualities.—*The Polymer Corp., Reading, Pa.*

Principal-strain Computer

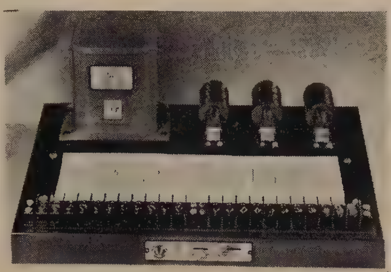
A new electronic computing instrument for automatically indicating and computing principal strains operates directly from equiangular, rectangular, or tee-delta, strain-gage rosettes. A total of 48 rosettes, of either the 3- or 4-gage variety, can be connected to the computer. To adjust for different gage arrangements, it is merely necessary to operate a single selector switch. After each increment of strain is applied, the operator can read and record the major and minor principal strains and the principal angle just as fast as he can operate the rosette selector switch and read and tabulate the results. The rosettes are powered by a 400-cycle carrier, and all operations in the calculations are performed on this carrier without any modulation or demodulation, and the waveform and frequency are not critical.



The computer contains within one cabinet all the oscillators, amplifiers, and power-supply equipment for operation directly from a single source of 115-volt 60-cycle power. A total of 75 vacuum tubes are used.—*Hathaway Instrument Co., 1315 So. Clarkson St., Denver 10, Colo.*

Magnetic Amplifier

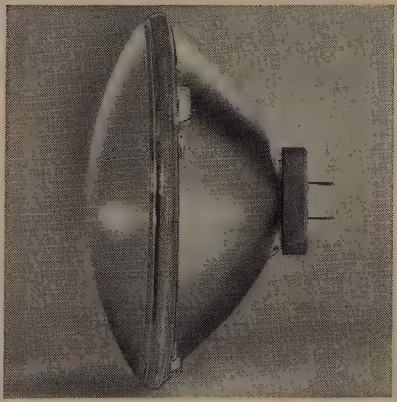
With magnetic amplifiers assuming a role of increasing importance in control applications a demonstration unit has been designed for educational purposes in schools and industry. The unit is so arranged that all basic single-phase self-saturating circuits can be studied. Because the characteristics of amplifiers connected for d-c and a-c output and control differ, it is important to be able to study all of these circuits and their combinations. Included with each unit are wiring diagrams of control circuits, as well as laboratory experiments arranged to help the student determine static and dynamic characteristics, internal impedance and optimum load, and types of control current.—*Vickers Electric Division, 1815 Locust St., St. Louis 3, Missouri.*



Resin

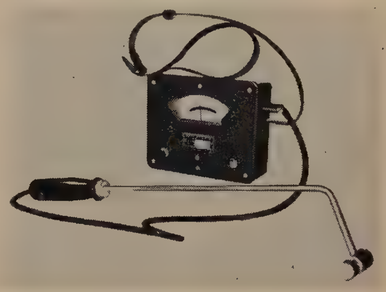
A new synthetic thermosetting resin, called Resinox 4846, especially designed for use as a core sand binder. The product is an efficient rapid-curing phenolic of high bond strength and low cost devised to meet the exacting requirements of the foundry industry. A wide range of core properties obtainable includes high tensile strength, high baked permeability, resistance to abrasion, rapid baking without green center, excellent detail and dimensional stability, and collapsibility and shake-out.—*Monsanto Chemical Co., Plastics Div., St. Louis 4, Missouri.*

Spot Lamp



A new 300-watt narrow-beam spotlight lamp of the all-glass sealed-beam type designed for applications requiring a spot of high intensity for the longer throws indoors from high ceilings and for numerous outdoor uses. The lamp projects a beam of approximately 15 degrees; its base is of the mogul end-prong type. The lamp, designed for any burning position, has a life rating of 1000 hr. It should be supported by its rim only, and for outdoor use a proper housing should be used to protect the bulb from rain and snow. At present the lamp is available only in lighting equipments which manufacturers are designing for its use. Later, it will become available separately, for replacement needs.—*General Electric Co., Lamp Dept., Nela Park, Cleveland 12, Ohio.*

Indicator Meter



A new portable direct-reading indicator for the determination of the ratio of lead and tin content in solder. With this indicator meter, up to 7 percent tin content of lead alloys can be tested in a matter of seconds. Application of this instrument by users of solder, such as manufacturers of tin cans, etc., eliminates time-consuming laboratory tests and results in considerable savings and improved product quality.—*Wheelco Instrument Co., 847 W. Harrison St., Chicago 7, Illinois.*

Pump Fluid

A new di-2-ethylhexyl sebacate Narcoil-20 diffusion-pump fluid specially treated for high-vacuum use. This ester is capable of attaining low pressures, and it can be used in any diffusion pump for service when pressures of less than 0.1 micron are required. It is available in pint, quart, and gallon containers for laboratory to plant-scale applications and it should be of particular interest to large users of diffusion-pump oil, such as cathode-ray tube manufacturers.—*National Research Corp., 70 Memorial Drive, Cambridge, Mass.*

Tantalytic Capacitor

A new 1-microfarad 150-volt d-c Tantalytic capacitor for use in electronic apparatus. A size reduction up to 90 percent of that required by paper capacitors and the promise of much longer life are two of its advantages made possible by the use of tantalum in foil form together with a special noncorrosive electrolyte. Designed for applications where small size and superior performance are the major factors, this hermetically sealed electrolytic capacitor offers longer shelf life, greater stability, lower leakage currents, and better low-temperature characteristics than conventional electrolytic capacitors.—*General Electric Co., Apparatus Dept., Schenectady 5, N. Y.*

Attachment for Jackbit

A new attachment permits realization of the full drilling economies possible with the long-wearing Carset jackbits. It is of the shoulder type, employing a 38-deg reverse-buttress thread, developed particularly to resist shock and impact while still preventing slippage, excessive thread wear, or loss of drilling speed. The form, pitch, and size of thread have been selected to give both attachment and bit maximum thread life. The effect of the matching 38-deg surfaces is to cushion and absorb the destructive reciprocating and rotational forces that tend to ruin bit threads or to break the threaded extensions on drill rods. The threads on this attachment are designed to last the life of the bit. Four sizes of attachments are offered to cover bit gage sizes from 1⅜ in. to 3 in.—*Ingersoll-Rand Co., 11 Broadway, New York 4, N. Y.*

Plug-in Busway

LTG Flex-A-Power is a new kind of plug-in or trolley busway for lighting, small power tools, business machines, and appliances. Rated 50 amp, 250 volts, it makes two, three, or four circuits available in one neat, compact housing and allows independent control over each. The equipment becomes an overhead electric power highway formed by a steel housing which encloses its copper bus bars. It may spread out like a whole network of highways to carry power over the full length and breadth of a plant or building. Unlike conventional wiring systems, which require outlets to be fixed at selected spots, every inch of this system is a potential outlet that may be tapped by two devices—an insert plug or trolley—not at special places, but at any point along the run.—*The Trumbull Electric Mfg. Co., Merchandising Division, Plainville, Conn.*

Ball-bearing Lubricant Tester

A compact, semiportable device for low-temperature testing of ball-bearing lubricants eliminates the need for elaborate cold rooms. Heart of the device is a cooling chamber which resembles a large bucket with a smaller bucket inside it, both being covered by a transparent plastic lid. Dry ice is placed in the space between the inner and outer buckets. For testing, a bearing is placed on a spindle in the inner bucket and rotated by a small electric motor. The tendency of the outer ring of the ball bearing to move with the inner ring is measured by a strain gage. If the lubricant under test thickens in the cold atmosphere, the inner ring will not turn freely, and the gage will register a greater strain on the outer ring.—*General Electric Co., Works Laboratory, Schenectady 5, N. Y.*

Waveform Monitor

A new waveform monitor, Type 5034-A, designed for use in TV broadcast installations. A cathode-ray tube displays the r-f carrier voltage on a linear time base at either field- or line-frequency. Further provision is made for measuring the relative amplitude of the various portions of the r-f envelope within prescribed accuracy limits. The meter is calibrated to read the modulation level directly as percentage of peak signal. Features of this monitor include: self-contained power supply; less than 10 watts of peak r-f power required to produce a peak-to-peak deflection; simple gas-triode linear circuit; band-pass circuits factory-adjusted to any one of the 12 commercial TV channels.—*Allen B. DuMont Laboratories, Inc., Transmitter Div., 1000 Main Ave., Clifton, N. J.*

Photoelectric Eyes

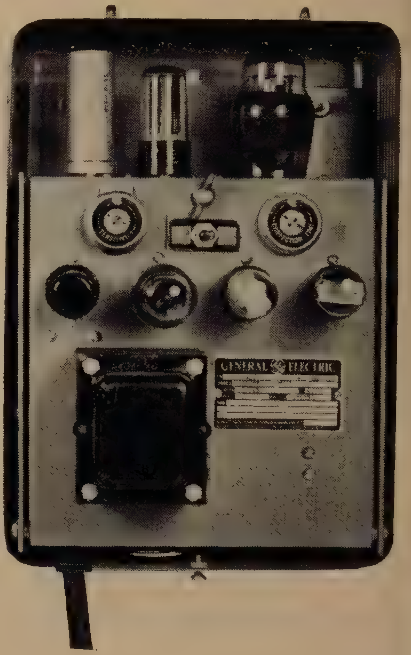
A new standard line of accessories for photoelectric relays, consisting of a complete range of improved light sources and phototube holders. The light sources are available at prices less than half those of previous models; the phototube holders are about 18 percent less. Snap-on covers for the light sources make lamp replacement possible in about 20 sec. No screws, hardware, or small parts need to be juggled in the process. In addition, prefocused lamps are used throughout, assuring that the filament is in the proper position in relation to the transmitting lens of the light source. These new accessories can be applied with photoelectric relays for counting, signalling, limiting, controlling, or protecting.—*General Electric Co., Control Divisions, Schenectady 5, N. Y.*

Carbide Gages

New reversible thread-plug carbide gages, offered in all sizes from 5-40, NC, NF, NEF, as well as special sizes, give maximum gage life, thus reducing inspection costs. Their accuracy results in passage of piece parts which might normally be rejected for rework or scrapping, a feature which provides for more economical operating costs.—*Size Control Co., 2500 W. Washington Blvd., Chicago 12, Ill.*

Register Controls

A new line of one-way cut-off register controls designed to solve the problem of accurately and automatically cutting a web of preprinted material into predetermined lengths so that the printed matter consistently appears at the proper point. For simplicity this line consists of two panels; heretofore five were required to cover the same range of applications. One of the panels, utilizing a thyratron output tube, is applicable to machines having cam-operated automatic reset switch. The other panel, utilizing a vacuum tube and a built-in electronic timer circuit, is applicable where machine timing is not desired. Both panels include voltage regulator tubes to compensate for variations in line voltage—*General Electric Co., Control Divisions, Schenectady 5, N. Y.*



Line Wire

Polyethylene covered aluminum line wire, a completely new electrical conductor possessing marked advantages where weatherproof or covered wire is desired. The covering is offered in a full size range of solid and stranded aluminum conductor, as well as small sizes of aluminum cable steel reinforced. This type of covered wire is a smooth, clean, nonsticky plastic material, black in color, with superior resistance to moisture, sunlight, weather hazards and abrasion. Advantages include economy, light weight, free stripping, resistance to abrasion and fungi, no festooning, and long lengths that can be readily handled because of light weight.—*Kaiser Aluminum & Chemical Sales, Inc., 1924 Broadway, Oakland 12, Calif.*

TRADE LITERATURE

Air And Hydraulic Power—A booklet designed to provide a more complete understanding of air and hydraulics and the many possible applications for using these types of power. Shown are a number of circuit diagrams indicating how air and hydraulics may be applied to industrial equipment. Eight pages.—*Rivett Lathe & Grinder, Inc., Brighton 35, Boston, Mass.*

Control Linkage—A leaflet presenting control connecting linkage for use with Bailey control drives. It contains engineering and price data to permit choosing the correct material and arrangement to best suit individual applications. From the data given requirements can be ordered by part number from the stock of standard parts and assemblies. Sixteen pages. General Specification CA 942.—*Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.*

Electric Timing Motors—An informational catalog of interest to users of electric timing motors as components of their products. A full line of standard motors is shown, complete with photographs, dimensional drawings, circuit diagrams, and data on standard specifications and ratings of each unit. Eight pages. Catalog No. 322.—*Haydon Manufacturing Co., Inc., Torrington, Conn.*

Feeders—In addition to a complete description of the Pecco vibratory bowl feeder for small parts, several application sketches illustrate its use in counting, washing, coating, and degreasing; handling delicate and fragile parts; and removing foreign matter. Four pages—*Perry Equipment & Engineering Co., 810 West 18th St., Erie, Penna.*

Motors for Business Machines—A comprehensive presentation of the construction, performance, characteristics, and ratings of fractional-horsepower motors for business machines including typewriter motors, adding machine motors, and series motors for calculators and portable accounting machines. Outlines the services available for handling specific application problems. Eight pages. GEA-5420.—*General Electric Co., Apparatus Dept., Schenectady 5, N. Y.*

Purifying Equipment—Three specially prepared bulletins offer solutions to power interruptions, engine breakdowns, and other utility problems resulting from contaminated turbine, lube, and insulating oils, and Diesel fuel. One bulletin explains the right method together with equipment necessary to maintain a continuous supply of clean oil during turbine or Diesel operation. Four pages. Titled "Absolute Certainty." Another describes the purification, dehydration, and degasification action of the portable Houdaille Purivac on oxidized insulating oils in transformers and circuit breakers. Four pages. Titled "Purivac." The third bulletin presents the application of oil purification equipment to typical utility problems. Four pages. Titled "You Name the Oil."—*Honan-Crane Corp., 949 Sixth St., Lebanon, Indiana.*

Reels—Presents the Toroidal light-weight steel reel as the modern answer to a common problem among shippers and users of electric, telephone, and power cable. Also provides interesting data on comparative delivery costs. Twelve pages. Titled "Report on Reels."—*George Evans Corp., 208 S. La Salle St., Chicago 4, Ill.*

Solvent Vapors—A report of an investigation to determine the lower limit of flammability and the autogenous ignition temperature of certain common solvent vapors encountered in ovens. Sixty-four pages. Bulletin of Research, No. 43.—*Underwriters' Laboratories, Inc., 207 East Ohio St., Chicago 11, Illinois.*

Stainless Steel—Concisely presents a discourse on the properties of stainless steel, and outlines the proper grades to use for parts subjected to heat. Ten general suggestions are given for selecting the best type of stainless steel for a particular heat-resisting application. Graphs and photographs supplement the descriptive text. Twelve pages. Titled "Stainless Steel for Heat Resistance."—*Armco Steel Corp., Middletown, Ohio.*

Turbidimeter—A loose-leaf 5-hole punch sheet giving the features, application, theory of operation, and description of the recording turbidimeter for continuous turbidity measurement. Two pages. GEC-571. —*General Electric Co., Apparatus Department, Schenectady 5, N. Y.*

BOOK REVIEWS

(Available books may be purchased through the GENERAL ELECTRIC REVIEW *for domestic delivery; none sent on approval.)*

Electronics: Experimental Techniques (National Nuclear Energy Series—Div. V. —Vol. I)

Wm. C. Elmore and Matthew Sands—McGraw-Hill Book Co., Inc., New York. 1949. xviii+417 pp. $3.75.

This is a manual of electronic circuits useful in the field of physics research. Circuits described were found by scientists of the Los Alamos Laboratory to be the most useful and the most successful for making nuclear and other physical measurements.

Brief treatment in the first chapter of the characteristics of electronic circuit components is followed by construction practices for laboratory electronic equipment, illustrated by a number of photographs.

The second chapter describes basic circuit elements, the building blocks of electronic circuitry—linear networks, linear electronic amplifiers, trigger generator circuits, and other nonlinear electronic elements.

The remainder of the book gives detailed descriptions of, and design procedure for, more complete items of electronic gear such as voltage amplifiers of various types, electronic counters, oscillographs, test and calibration equipment, power supplies, and control circuits.

The book is well indexed, and should be of use to physics laboratory students and research workers. Many of the circuit diagrams shown include complete circuit constants; thus they can probably be readily constructed and put into use with a reasonable assurance that they will function satisfactorily.

H. W. Lord

Never Too Old

N. Y. State Joint Legislative Committee on Problems of the Aging. 1949. 216 pp. Free while they last. (Write Thomas C. Desmond, Chairman, 94 Broadway, Newburgh, N. Y.)

This series of studies of many phases of the problems of the older worker, with stress on continued employment, is made by persons eminent in their field, and is well documented by appendices.

Emphasis is laid on the treatment of each employee as an individual, with the resulting statement that no universal predetermined retirement age can be set.

While not in entire accord with all our theories on employment of the elderly worker—for example, compulsory retirement—this study does an excellent job as far as it goes. The problem of the older worker is examined through a proposed state-wide program of re-creation of life for the older worker, and a co-ordinated plan of activities has been suggested. The part of industry in solving this problem is seen as providing financial security to the limit of its ability through pensions, through more efficient health facilities, and through tolerance of the older worker. Of course, the worker must help himself in the adjustment for his old age. He must take advantage of the advances in medical science by participating in clinics for the discovery of chronic ailments, condition himself psychologically for retirement, adjust himself economically, and make any other necessary readjustments for his rehabilitation.

One might say the committee found that

> ". . . age is opportunity no less
> Than youth itself, though in another
> dress,
> And as the evening twilight fades away
> The sky is filled with stars, invisible
> by day."

Ruth E. Bennett

Introduction to Radiochemistry

Gerhart Friedlander and Joseph W. Kennedy—John Wiley & Sons., Inc., New York. 1949. xiii+412 pp. $5.00.

Two recognized experts in radiochemistry have been able in a very readable and succinct manner to convey to the reader a basic understanding of the scope and the techniques employed in this field of chemistry. This is accomplished by including details of actual experiments and experimental methods which are of great value to both students and laboratory workers.

(Continued on following page)

BOOK REVIEWS (Continued)

Although the chapter headings in the Table of Contents resembles that of a modern textbook on nuclear physics, the text reflects accurately the approach of the radiochemist to these problems. Implicit in this observation and obvious to the reader is the basic role that the chemist plays in modern nuclear science and the fact that the developments in this field are the result of a firm partnership between chemist and physicist, with the dividing line between the two fields completely obscure.

Chapter IX, which concerns the statistical aspects of radioactivity, merits especial mention. In the original Los Alamos lectures this phase was presented by Dr. R. Dodson, and its inclusion in the present text rounds out an already excellent book, making it outstanding as a textbook for college instruction and for practicing chemists.

L. P. Pepkowitz

Aerials for Metre and Decimetre Wavelengths

R. A. Smith—Cambridge University Press, New York. 1949. xii+218 pp. $3.75.

This small but most excellent book, one of a series on Modern Radio Technique by various British authors deals with its subject in a thoroughly able and authoritative manner, albeit somewhat more briefly than most radio engineers would prefer. The author has arranged his material in a very logical manner and writes in a style that is easy to read and understand. For the most part he avoids nonessential mathematics—a difficult procedure in this highly mathematical field—and yet does not hesitate to employ integrals whenever their use will contribute to clarity or usefulness.

The first five chapters cover fundamentals common to all aerials in the meter and decimeter range, with a particularly excellent chapter on the fundamental theory of radiation. Following chapters deal with specific types of aerials, and the book closes with an excellent chapter on noise in aerials. The references listed at the end of each chapter are particularly well chosen and cover the field thoroughly. This is a welcome addition to the technical literature of radio engineering.

C. A. Priest

Industrial Electronics

Andrew W. Kramer—Pitman Publishing Corp., New York. 1949. xi+311 pp. $6.00.

In recent years there has been increasing application of electronic control and measuring systems in manufacturing. Nearly every branch of industry now depends in some way on electronic devices.

However, there are still many unsolved problems to which electronics may offer a solution. The purpose of this book is to stimulate interest in electronics among those concerned with such problems. Intended for those who have an engineering background but are not primarily engaged in electronics work, it is a nonmathematical treatment of the subject, with very careful explanation of fundamental concepts.

In a logical order, the author makes sure that each concept is thoroughly understood before introducing any new ideas. Although a few points seem a little over-emphasized, in general he has made an excellent selection of topics and handles them very well. Over half of the book is devoted to explaining the fundamental concepts; some of the explanations are excellent and worthy of study by experienced electronic engineers. The remainder of the book is devoted to a brief survey of specific applications of electronic systems.

Even though credit is given for sources, it is to be regretted that a more complete bibliography is not included. Diagram and figures are simple and clear.

In general this is an excellent book and fulfills the purpose for which it was intended.

T. M. Wilson

An Introduction to the Mechanics of Viscous Flow

H. F. P. Purday—Dover Publications, Inc., New York. 1949. 191 pp. $2.75.

Three subjects are covered here: the mechanics of nonturbulent flow; the flow of heat by conduction; and heat transfer between solids and fluids in nonturbulent flow. The treatment is mathematical and intended to show the underlying similarity of the three subjects.

In this pocket-size book, published in England as *Streamline Flow*, only a highly condensed treatment has been possible. As a result, considerable study is required in its use, and its principal value is as a handy-sized reference work.

Chapter themes include: viscous flow in pipes and channels; viscous flow between fixed parallel planes; films of varying thickness; sliding pads; journal bearings; viscous resistance of bodies; the flow of heat; boundary convection; convection in depth; orthogonal functions; and equations of flow.

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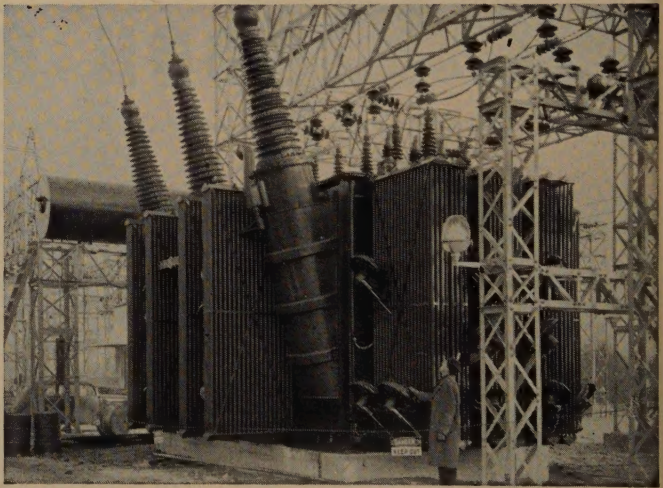

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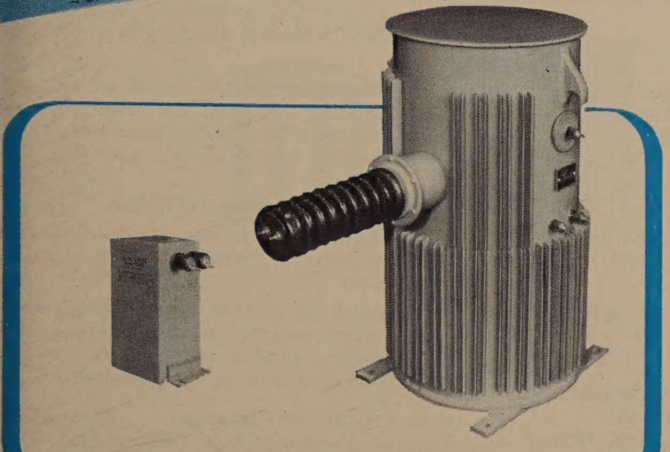

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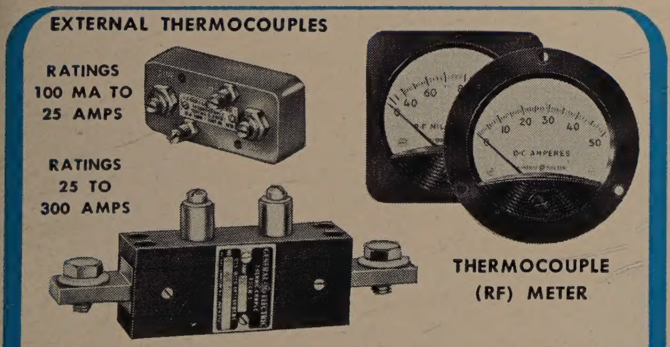

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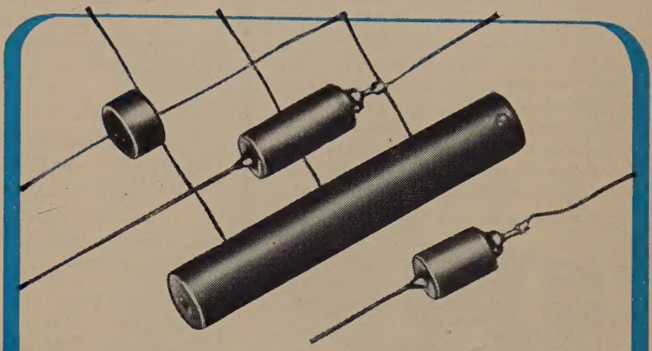

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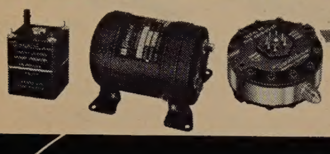

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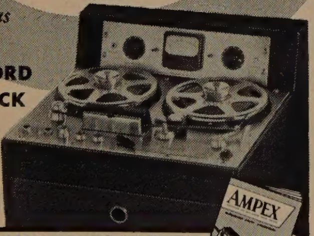

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Air Conditioning. J. C. McCabe. *Power*, Apr. 1950; v. 94, p. 75.

A special section devoted to principles, equipment, and operation.

Refrigeration and the Water Supply Industry. Elwood L. Bean. *Refrig. Engng.*, Feb. 1950; v. 58, p. 140.

Considers the effect of the growing water shortage in many U.S. cities and the serious shortage now existing in New York City on existing and future installations of refrigeration and air-conditioning equipment.

BEARINGS

Bearings for Intermittent, Oscillatory Motion. R. R. Bush. *Mach. Design*, Jan. 1950; v. 22, p. 117.

Describes bearings for power circuit breakers, with special reference to Textolite bearings.

Construction and Characteristics of Low-cost Ball Bearings. F. W. Rechnagel. *Prod. Engng.*, Jan. 1950; v. 21, p. 106.

How to select low-cost commercial ball bearings for various speed and loading conditions. Classification of standard types for radial and/or thrust loads. Modifications that can be made for special design, assembly, or operating conditions.

ELECTRIC CURRENT RECTIFIERS

D-c Arc Source and Automatic Controller. G. H. Fetterley and W. M. Hazel. *Optical Soc. of Am. Jour.*, Feb. 1950; v. 40, p. 76.

Describes a rectifier circuit as an effective source of direct current up to 45 amperes at 150 volts and an automatic current-controller circuit.

Metallic Rectifiers: Is Poor Testing Raising Your Costs? Edgar A. Harty. *Factory Man. & Maint.*, Feb. 1950; v. 108, p. 115.

Describes the assembly of stacks, testing, replacing stacks, and reasons for failure.

ELECTRICAL MACHINERY

Design of Purging Systems for Hydrogen-cooled Electric Machines. D. S. Snell and R. C. Schmid. *Power Gen.*, Feb. 1950; v. 54, p. 54.

A complete description of the methods which have been developed for the purging of hydrogen-cooled electric machines by the use of carbon dioxide, with all the necessary technical data on the characteristics of the fluids involved under various conditions of pressure, temperature, and mixture.

"Hot Spot" Motors. C. R. Sutherland. *Elec. Mfg.*, Mar. 1950; v. 45, p. 94.

Cooling by either water or air, shielding from radiant heat, use of low heat-transmitting shaft material, proper bearing design, and choice of lubricant are some of the means described to assure dependable operation of motors for high-temperature machinery drives.

FOUNDRY PRACTICE

Continuous Casting of Brass Slabs. Harold J. Roast. *Metal Prog.*, Jan. 1950; v. 57, p. 51.

Describes the operations of a new mill for the production of coiled brass strip in extra-long lengths.

Cupola Dust Collection. William N. Witheridge. *Foundry*, Feb. 1950; v. 78, p. 84.

The first of two articles on the subject of cupola dust collection; discusses properties and quantities of emissions from the cupola under various operating conditions.

MEASURING INSTRUMENTS

Electronic Pressure and Displacement Instruments. *Diesel Power*, Feb. 1950; v. 28, p. 49.

Describes the Electro Pressuregraph for measuring pressure variations in internal combustion engines and pumps whose duration is as brief as 0.001 second.

How to Compare Counters. Alexander Thomas. *Nucleonics*, Feb. 1950; v. 6, p. 50.

The comparison of sample and background measurements—made easy by the equations given in the article—is emphasized.

Traveling-wave Oscilloscope. J. R. Pierce. *Electronics*, Nov. 1949; v. 22, p. 97.

Experimental 1000-volt tube, developed especially for examination of short recurrent pulses, has almost flat response from 0 to 500 mc. Optical magnification of the pattern is employed.

STEEL

New Methods for Determining Phosphorus in Steels. *Steel*, Jan. 30, 1950; v. 126, p. 46.

Includes spectrographic method using Geiger photoelectron tubes, recently adopted for production control of phosphorus in steels.

New Precipitation-hardening Stainless Steels. G. N. Goller and W. C. Clarke, Jr. *Iron Age*, Mar. 2, 1950; v. 165, p. 86.

Describes two new steels, 17-4 PH and 17-7 PH, employing copper and aluminum instead of carbide formers as precipitation-hardening elements, for corrosion resistance plus high-strength properties.

WELDING

Welding in an Aircraft-engine Plant. George H. DeGroat. *Mach.*, Feb. 1950; v. 56 p. 153.

Describes techniques employed by on manufacturer in fabricating the velocit turbines for the turbo-cyclone engine.

Welding Stainless-steel Pipe. Alle J. Ely, Jr. *Heat. & Vent.*, Feb. 1950; v. 47 p. 63.

Part 1 of a two-part article covering basi information regarding the welding c stainless-steel pipe and factors to b considered.